TEXAS HOUSE OF REPRESENTATIVES

COMMITTEE ON ENVIRONMENTAL AFFAIRS

REPORT ON THE IXTOC I OIL SPILL

TEXAS COASTAL AND MARINE COUNCIL

POST OFFICE BOX 13407 / AUSTIN, TEXAS 78711

BENNIE BOCK II
CHAIRMAN

MARCH 10, 1980

FOREWARD

On March 24, 1980, the nine month long struggle to cap the IXTOC I oil well came to an end. Mexican officials announced that the well was successfully capped. It is estimated that more than 130 million barrels of oil spilled into the Gulf of Mexico since June 13, 1979 making this spill the largest ever recorded.

House of Representatives
Committee on Environmental Affairs

March 26, 1980

Rep. Bennie Bock II, Chairman
New Braunfels

Vice-Chairman
Rep. Carlyle Smith
Grand Prairie

Vice-Chairman
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Rep. Tim Von Dohlen
Goliad

Rep. Ed R. Watson
Deer Park

Committee Clerk
Arlene Wilson

The Honorable Bill Clayton
Speaker
Texas House of Representatives

Dear Mr. Speaker:

The Committee on Environmental Affairs respectfully submits its report on the IXTOC I oil spill in accordance with your charge to the committee.

Sincerely yours,

Bennie Bock II

Bennie Bock II
Chairman

Carlyle Smith

Carlyle Smith, Vice-Chairman

Fred Agnich

Fred Agnich, Vice-Chairman
Appropriative Matters

Henry E. Allee

Henry E. Allee

Ronald Bird

Ronald C. Bird

Jerry Clark

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Frank Collazo Jr.

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Nolan J. Robnett

Nolan J. (Buzz) Robnett

Bill Sullivant

Bill Sullivant

Tim Von Dohlen

Ed Watson

Ed Watson

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INTRODUCTION

On June 3, 1979, the Petroleos Mexicanos (PEMEX) oil well blew out and ignited in the Bay of Campeche which is 500 miles south of the coast of Texas. (See Map) The well, known as the IXTOC I, has spilled more than 3 million barrels of oil into the waters of the Gulf of Mexico. As of this writing the well has still not been capped. Until early July, 1979, the spill remained near the wellhead. Seventy days after the blowout, oil appeared in Texas waters and on Texas beaches in the form of tar balls, "mousse" (oil weathered to a fudge-like consistency), and slicks. Beaches were affected from Port Aransas to the mouth of the Rio Grande. In September, changes in the prevailing winds and currents caused the oil to stay in Mexican waters. When the currents resume their northerly flow, the oil could again threaten the Texas coastline.

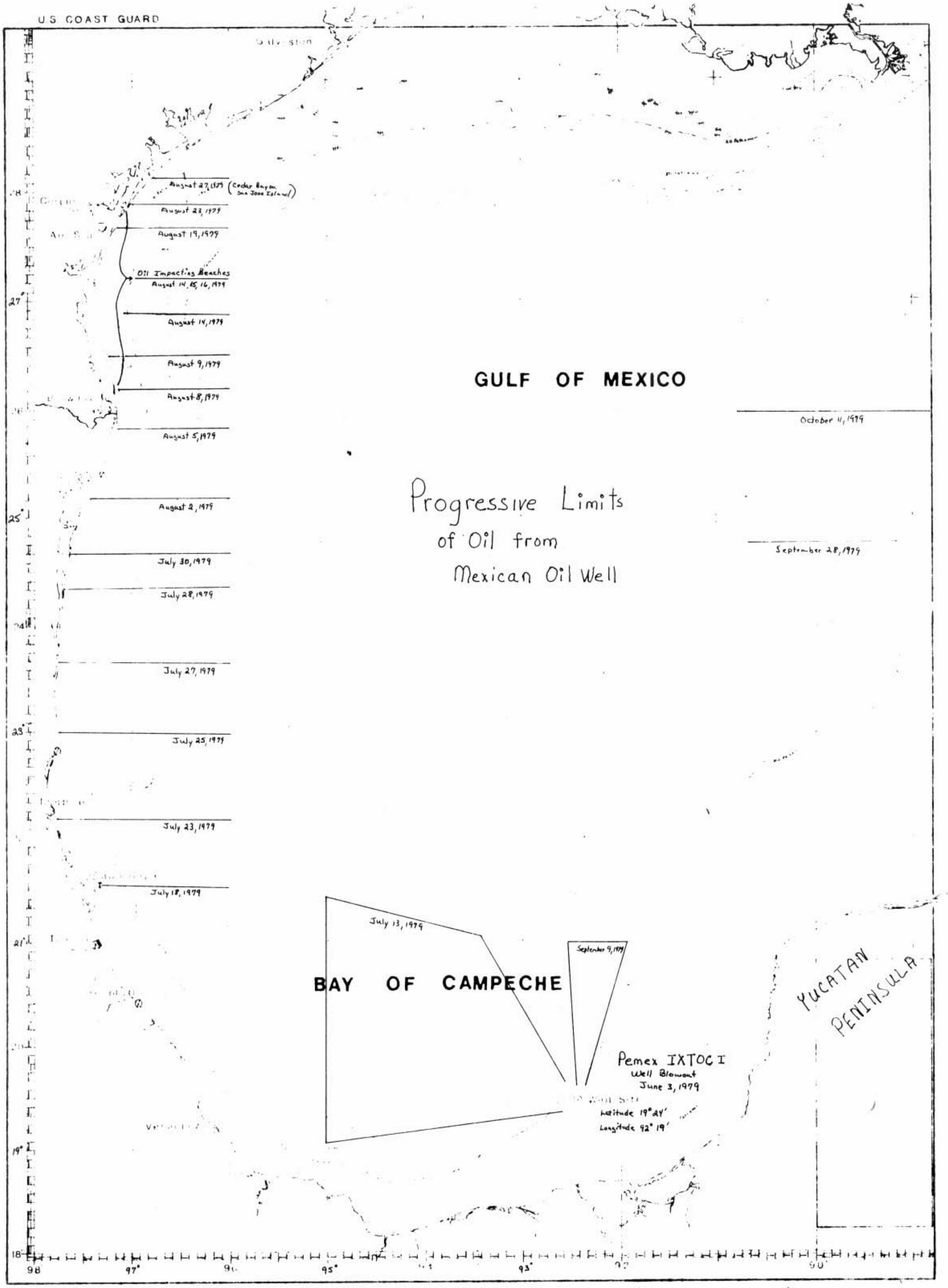
Concerned that the oil from the spill affected a large area of the Texas coast, tourism, the fishing industry and possibly human health and the environment, Rep. Bill Clayton, Speaker of the Texas House of Representatives, assigned the Committee on Environmental Affairs, chaired by Rep. Bennie Bock II, to conduct a study on the oil spill's effects.

This report attempts to answer the following charges (as presented by the Speaker):

1. monitor the effects, immediate and long-term of the blowout, on the coastal environment;
2. evaluate the effectiveness of the cleanup effort and the Oil Spill Contingency Plan;
3. review federal, state, and local policies regarding assistance for natural and manmade disasters; and
4. determine if changes in State law are needed to address issues which include, but are not limited to, financial disaster aid.

At the time of the above charge to the committee, it was not anticipated that part of the problem would be the capping of the well. This report was delayed several months awaiting the capping of the well, and as of the date of this report the well still has not been plugged. Until the flow of oil is stopped, there is no way

U.S. COAST GUARD



to assess the final damages. Consequently, this report will attempt to document those answers that can be made with the obvious limitations.

On August 24, 1979, the Committee on Environmental Affairs held its first meeting in Corpus Christi to learn what action was being taken to safeguard the Texas coast. Various federal and state officials described their functions regarding the oil spill crisis.

On October 16, 1979, the Committee met again to discuss safeguards to prevent blowouts from occurring. Preventive training and educational programs were discussed. The Committee also heard testimony about developing oil spill cooperatives in the state.

In addition to the hearings, the Committee sought comments from the federal and state agencies, the universities, and industry. The Texas Department of Water Resources cooperated fully with the committee and continues to send progress reports concerning the flow of the oil as well as the cleanup operation. The General Land Office prepared a chart and supporting documentation showing the authority of the state to regulate oil, gas, and related operations to prevent oil spills. (See Appendix E)

In order to fulfill the request of the Speaker of the House to undertake an in-depth study of the threats posed both to the coastal environment and the economy of Texas by the Mexican oil spill, and at the request of the Speaker, the Committee on Environmental Affairs engaged the services of the Texas System of Natural Resources (TSNL) on a staff basis to assist in the evaluation process of the environmental impact.

FEDERAL/STATE CONTINGENCY PLANS

The National Oil and Hazardous Substances Pollution Contingency Plan[1] was developed in compliance with the Federal Clean Water Act of 1977.[2] This plan seeks to insure a coordinated Federal response at the scene of a discharge of oil or hazardous substance. The On-Scene Coordinator (OSC) coordinates and directs the Federal response to spills, and discharge removal efforts at the scene of a discharge. The Coast Guard is charged with providing the OSC in the coastal regions of the United States. (See Figure I) The Environmental Protection Agency has that responsibility in inland regions.

The state government is represented on the Regional Response Team (RRT) by the Texas Department of Water Resources (TDWR) and provides advice and assistance to the OSC. At the request of the OSC, state resources can be utilized directly to pick up or contain spills.

In addition to the clean-up activities conducted under the federal fund set up under Section 311 of the Federal Clean Water Act of 1977, clean-up activities can be conducted under subchapter (g), "Coastal Oil and Hazardous Spill and Prevention Control" of the Texas Water Code.[3] These activities must be conducted in accord with the National Contingency Plan. The executive director of the TDWR places the resources of the state at the disposal of the OSC, if he is present, or engages in cleanup activities when directed to do so by the OSC. (See Figure II) When no OSC is present and no action is being taken by an agency of the federal government, the executive director of TDWR may act to clean up oil under Section 26.264(h)(2). (See Figure III)

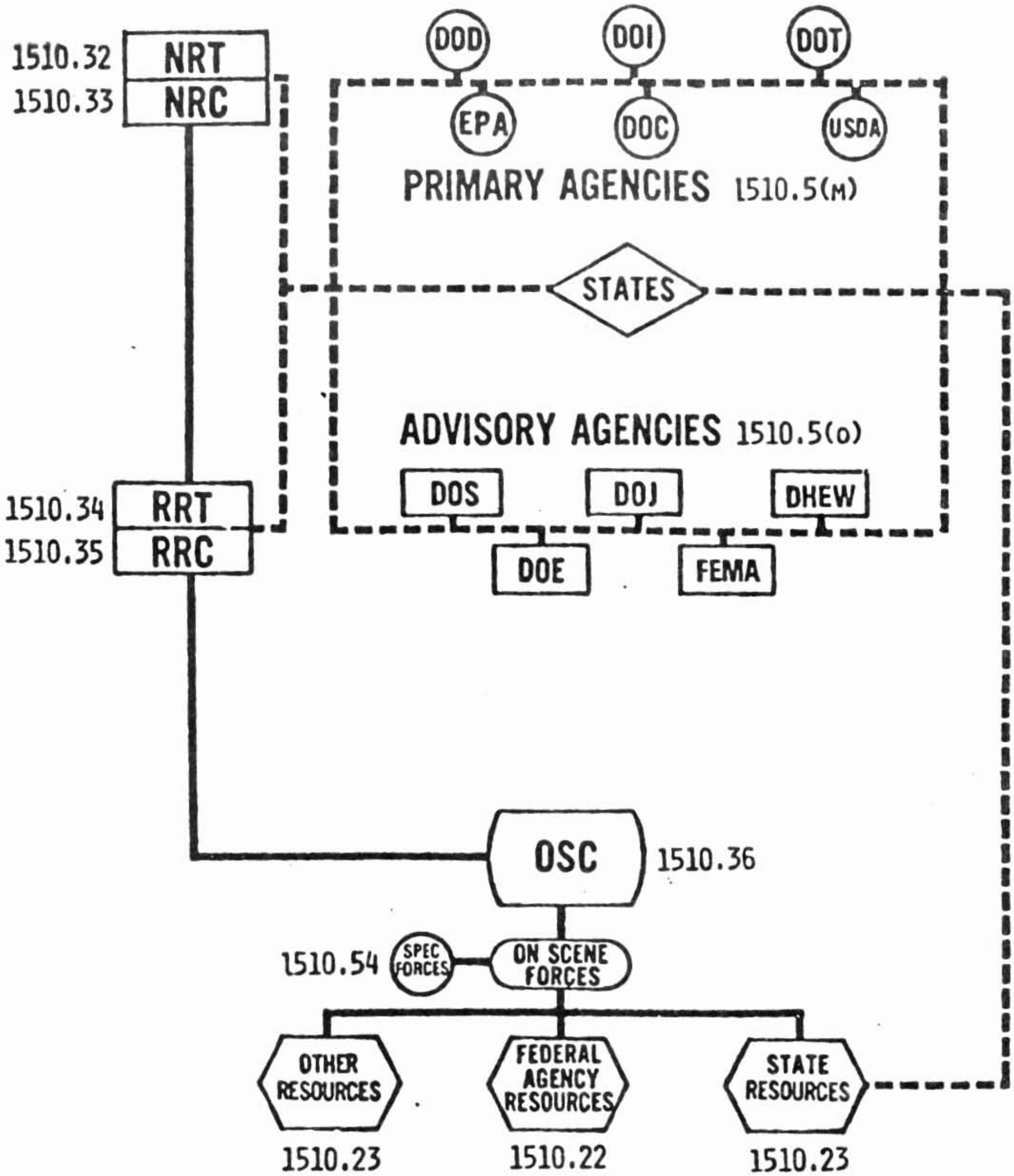
Pursuant to Section 26.264(f), the TDWR and the State Department of Highways and Public Transportation (TDHW) have an existing contract relating to the manner in which Highway Department resources are to be used.

Also relating to oil spill cleanup is the State of Texas Disaster Plan which provides for the coordination of state agency efforts in the event of disasters by the Division of Disaster Emergency Services of the Texas Department of Public Safety (DPS).[4]

FEDERAL INVOLVEMENT

Shortly after the IXTOC I well exploded in the Bay of Campeche, the United States Coast Guard began its preparations for the potential onslaught of oil in the waters of Texas. The command center and theregional news office were established in Corpus Christi. On July 27, 1979 Captain Roger Madson relieved Commander Joel Sipes as the Federal On-Scene Coordinator (OSC). The Scientific Coordinator was named, Mr. John Robinson of NOAA and LCDR James Paskewich

NATIONAL CONTINGENCY PLAN CONCEPTS

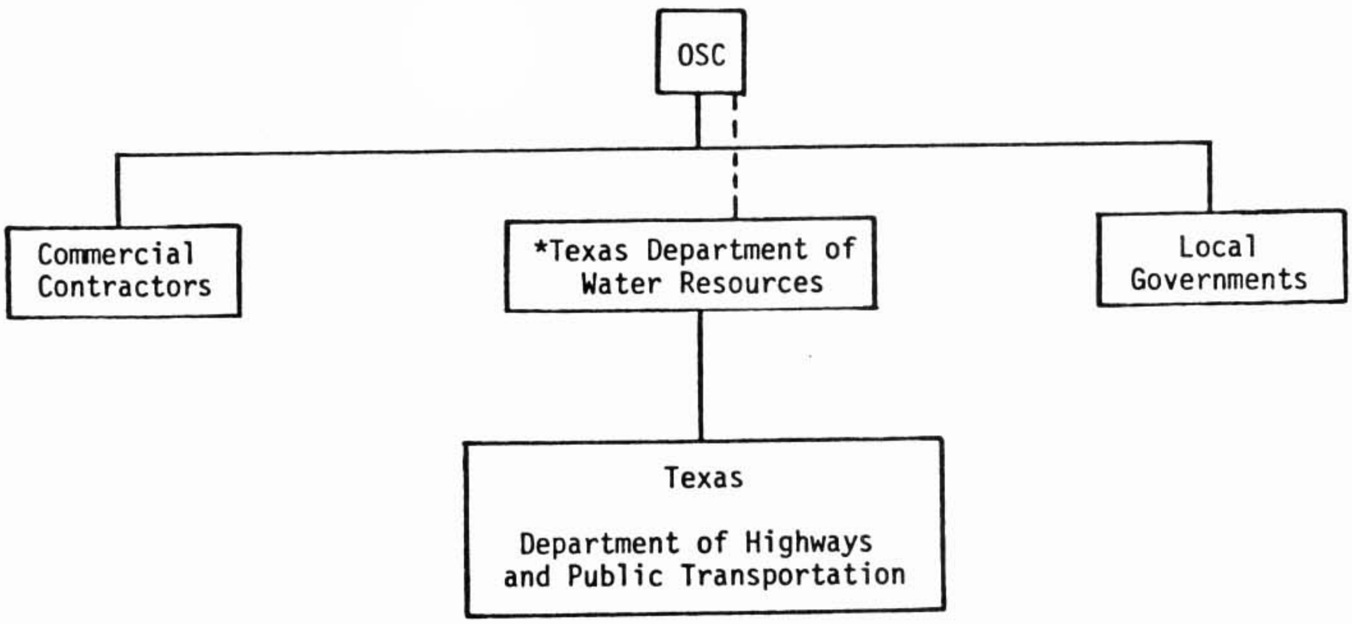


BILLING CODE 3125-01-C

FIGURE II

ORGANIZATIONAL CHART WITH RESPONSIBILITY FOR COASTAL OIL AND HAZARDOUS SPILL PREVENTION AND CONTROL

U.S. Coast Guard
On-Scene Coordinator (OSC)
(Present)



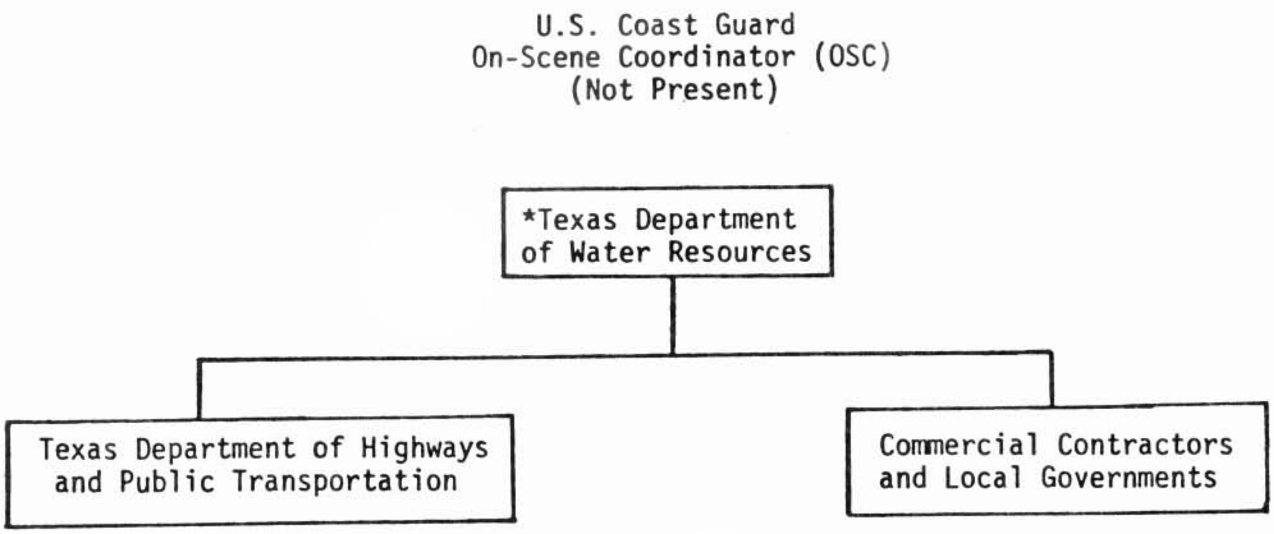
Authority for this Organization is given by the Texas Water Code, Subchapter G, Section 26.264(h) and Section 26.266(d).

* Section 26.264(h)(1) and (h)(3) applies specifically to this situation.

--- Indicates that State of Texas resources are at the disposal of the OSC.

FIGURE III

ORGANIZATIONAL CHART WITH RESPONSIBILITY FOR COASTAL OIL AND HAZARDOUS SPILL PREVENTION AND CONTROL



Authority for this Organization is given by the Texas Water Code, Subchapter G, Section 26.264(h) and Section 26.266(d).

* Section 26.264(h)(2) and (h)(3) applies specifically to this situation.

was named as the Response Coordinator. Representatives from other Federal agencies and the State of Texas were named to serve on the response team. A vulnerability study was conducted by Research Planning Institute (RPI) of Columbia, South Carolina to identify and map sensitive areas of the entire Texas coastline. In mid July, the U.S.C.G. cutter Valiant sailed with NOAA and EPA scientists aboard to obtain samples of the oil and also to chart the water currents in the Gulf. NOAA gathered data from the Coast Guard overflights in order to monitor the movement of the oil.

On August 24, 1979, Captain Roger L. Madson, U.S.C.G., testified before the Committee on Environmental Affairs. Captain Madson explained the National Contingency Plan and the role that the National Response Team and the Regional Response Team play in dealing with major oil spills. The Coast Guard, according to Captain Madson, decided that its first line of defense would be "to stop the oil from entering these bays and estuaries, and this would mean booming of the passes, starting at Brazos-Santiago, moving up to Port Mansfield, the Fish Pass below Aransas, and then Aransas Pass, itself."

When the oil was 60 miles below the Rio Grande, all organizations and equipment involved in the operation, were called in. The Navy Mark-O-Skimmer worked effectively on the mousse.

The strategy used by the Coast Guard, according to Capt. Madson's testimony, was to give highest priority to cleaning the beaches near the hotels and motels to minimize the economic impact as much as possible. Isolated areas of beaches were not cleaned at that time, stated Madson, because it was not economically feasible to clean 130 miles of beaches daily.[5]

STATE ACTIVITIES

During the 70 days from the blow out (June 3, 1979) until oil began to appear in Texas waters and on the beaches, several meetings were held to coordinate the spill response effort of state and federal agencies.

On July 13, 1979, a meeting of the Regional Response Team (RRT) was held at the Eighth Coast Guard District Headquarters in New Orleans. Dick Whittington, Deputy Director of the Texas Department of

Water Resources (TDWR) named by the Governor to be the state's representative to the RRT, outlined the state's strategy for bay and estuary protection and beach cleanup. The priorities of the plan were:

1 To prevent oil from entering bays, estuaries, and the the Laguna Madre by fill in or deploying booms across passes
2 To clean recreational beaches
3 To clean remote beaches[6].

On July 20, a meeting of all state agencies interested or involved in the spill response activities was held to obtain comments on the TDWR pass protection plans and beach cleanup strategy.

On July 27, the TDWR presented at the RRT meeting a strategy, which had been coordinated with other Texas state agencies, for protecting the bays up to the Colorado River. This strategy was later refined by the USCG strike teams and placed into effect.

On July 31, the TDWR staff personnel were permanently assigned to the USCG command post in Corpus Christi to represent the state. State-On-Scene Coordinator was John Latchford.

The following is a brief description of the roles of the other state agencies involved:

The Division of Disaster Emergency Services (DES) of the Texas Department of Public Safety (DPS) had the responsibility of continuous evaluation of the effects of the oil spill. Reports received from the Coast Guard and from DES contacts with authorities concerned with the slicks potential impact on the Texas coast were reviewed and reports were transmitted by message, telephone and personal contacts to the Governor's office.[8]

The General Land Office (GLO) monitored the coastline from Aransas County to Cameron County to assess the social, economic and environmental impacts of the oil spill on state lands. The GLO also designated potential holding sites as they were needed and coordinated information gathering with TDWR.[9]

The Texas Department of Health (TDH) collected samples of marine food organisms from all of Texas major bay systems for hydrocarbon testing before the oil arrived to provide a data base for determining the effect on the wholesomeness of Texas seafoods in the event that the oil invaded the bays and estuaries. The Department's Division of Food and Drugs conducted tests to determine if any seafood had been contaminated by the oil spill. No contamination was reported.[10]

The Texas Railroad Commission deployed remote weather stations and arranged for storage and salvage of recovered oil.[9]

The Texas Department of Highways and Public Transportation prepared disposal sites, closed passes, participated in cleanup of the beaches, transferred oil debris to its final disposal site, and constructed access roads where needed.[9]

The primary role of the Texas Parks and Wildlife Dept. was to monitor the fish and wildlife populations. The Department chemists also aided in bioassays and decisions on oil containment and cleanup.[11]

The Texas Air Control Board conducted burning tests as an alternative to oil removal technique.[9]

The Attorney General's office provided assistance in legal questions arising from the oil spill and the cleanup operations.[9]

RESEARCH

Texas beaches, bays and estuaries are irreplaceable assets of great value to the Texas coastal economy. In order to protect this valuable asset for the future, basic research is needed now to assess the oil spill of last summer.

Key processes[12] of the coastal ecosytem which must be understood include:

A. Productivity
   - carbon uptake
   - nitrogen uptake
   - fresh water input
   - input from swamps and marshes

B. Geochemical cycles
   - metals
   - pollutants
   - organics from rivers

C. Food web analyses
   - benthic role
   - seagrass role

- plankton role
- nitrogen fixation and nitrogen cycle

D. Physical and geological
- sedimentation rates
- water movement.

All existing baseline studies which contribute directly to long range key processes studies should be updated at the time of peak activity for all major disasters. The different samplings done on the IXTOC I spill and the Burmah Agate should take into account the existing Bureau of Land Management Outer Continental Shelf baseline studies. The sampling should be related to the USGS/BEG Core Sediments Archives using the same precise sampling latitude/longitude grid to which the original sampling is tied and to which other sampling also can then be related by latitude/longitude points.

A baseline is the norm against which the plus or minus effects of an impact can be measured using samplings taken at the time of "peak activity" and taken again after the fact. Four or five such major base line studies for Texas coastal waters and the outer continental shelf were completed from 1975 to 1977.[13]

Texas has a cooperative pair of resources which is unique in the nation. The State has the Texas Natural Resources Information System (TNRIS), and the universities have their private, non-profit consortium, the Texas System of Natural Laboratories, Inc. (TSNL). (See Appendix F)

The following document prepared by TSNL will consist of the International base line data coding system; profiles of an oil spill with a related one for fish and shrimp species; and also the biological aspects relating to the IXTOC I oil spill.

INTERNATIONAL BASE LINE DATA CODING SYSTEM

INTRODUCTION

PURPOSE: This outline is the TSNL categorization system for storage, retrieval, and interrelation of information drawn from a broad range of sources.

STORAGE AND RETRIEVAL: Since data may apply to more than one topic heading, it can be stored under all relevant topic headings and retrieved from any one of them. All data under a single topic can be retrieved by recalling that topic. By recalling two topics, only that information recorded under both topics (i.e., at their intersection) will be displayed. This information at the intersection of two or more topics will show relationships between outline factors.

GEOGRAPHICAL PLACEMENT: When available, information will be assigned geographical designations according to place names listed in an appendix. This assignment can be assumed where it is not specifically noted within an outline section.

INVENTORY AND DISTRIBUTION: The relationship between geographical location and any other outline category can be displayed in two ways. Either all references to a place (such as the soil types of a county) or all distributional information for a topic (such as the county distribution of a particular soil type) can be retrieved.

BIBLIOGRAPHY: All entries will be carefully referenced, and a source bibliography for any outline topic (or intersection of topics) will be available. A reference is stored under all relevant topic headings, not merely by title or key words as currently provided by most abstract services.

APPLICATIONS: This system is intended for use by researchers, managers, and planners in academic institutions, industry, and government. In addition to primary uses for teaching and research, it can facilitate the preparation and evaluation of impact statements and management decisions, ease time consuming literature searches, and provide inspiration for further research. Although not a model, this system is designed to provide an adequate data base and base line framework for modelers.

FEATURES: There are a number of advantages to this coding system. One is its design in outline form, implying relationships between factors, rather than as a simple list. Further detail can be developed as necessary. Also, the outline can supplement or interface with such diverse data systems as the Texas Natural Resources Information System or the United Nations Environmental Program. Unlike most other data systems, man is treated in the biological section.

November, 1978
Austin, Texas

TEXAS SYSTEM OF NATURAL LABORATORIES, INC.

INTERNATIONAL BASE LINE DATA CODING SYSTEM (IBLDCS)

DESCRIPTION:
TSNL's Master Outline (IBLDCS) is summarized here to the first three levels only to provide an overview of its scope. In its complete form some sections are subdivided down to 10 levels. It is designed so that further detail can be added on the lower levels to accommodate specific research and data storage needs.

A. BASE INFORMATION: PHYSICAL ASPECTS

- I. METEOROLOGICAL
  - A. Climatic belts
  - B. Wind
  - C. Precipitation
  - D. Temperature
  - E. Evapotranspiration rate
  - F. Solar radiation
  - G. Ultra-violet radiation
  - H. Visible haze
  - I. Photosynthesis
  - J. Climatic changes
  - K. Extraordinary weather events
- II. HYDROLOGICAL
  - A. Drainage Basin
  - B. River or stream reach
  - C. Water impoundments
  - D. Aquifers/ground water
  - E. Estuary/bay system
- III. GEOLOGICAL
  - A. Stratigraphic
  - B. Structural
  - C. Paleontological
  - D. Geomorphological
  - E. Economic
  - F. Environmental
- IV. PEDOLOGICAL
  - A. Classification
  - B. Geographical distribution
  - C. Description
  - D. Use capability
- V. CHEMICAL
  - A. Nitrogen cycle
  - B. Phosphorus cycle
  - C. Carbon cycle
  - D. Other geochemical cycles
  - E. Dissolved oxygen - aquatic
  - F. Chemical oxygen demand - aquatic
  - G. Biochemical oxygen demand - aquatic
  - H. Atmospheric gases
  - I. Total particulates
  - J. Common elements
  - K. Trace elements
  - L. Heavy metals
  - M. Radioactive substances
  - N. Herbicides and pesticides
  - O. Petroleum

B. BASE INFORMATION: BIOLOGICAL ASPECTS

- I. TAXONOMIC CLASSIFICATION
  - A. Viruses
  - B. Superkingdom Prokaryonta
    - Kingdom 1. Monera
  - C. Superkingdom Eukaryonta
    - Kingdom 1. Myceteae
    - Kingdom 2. Plantae (Phyta)
    - Kingdom 3. Animalia (Zoa)
- II. ECOLOGICAL CLASSIFICATION
  - A. Evolutionary history
  - B. Distribution
  - C. Habitat
  - D. Abiotic interactions
  - E. Biotic interactions
  - F. Biotic/cultural interactions
  - G. Cultural interactions

APPENDIX A: CAPITAL RESOURCES INVENTORY

- I. Natural resources
  - A. Air
  - B. Water
  - C. Land
  - D. Biological
  - E. Energy
- II. Utilization of resources
  - A. Agriculture, forestry and fishing
  - B. Mining
  - C. Construction
  - D. Manufacturing
  - E. Transportation, communications, electric, gas, and sanitary services
  - F. Wholesale trade
  - G. Retail trade
  - H. Finance, insurance, and real estate
  - I. Services
  - J. Public administration
  - K. Nonclassifiable establishments
- III. Limiting factors
  - A. Natural pressures
  - B. Man-made pressures
- IV. Educational resources
  - A. Research resources
  - B. Researchers
  - C. Research reports
  - D. Bibliography of sources

APPENDIX B: MANAGEMENT CONCERNS

- I. Managerial interests by industry
  - A. Industrial
  - B. Public administration
- II. Activities (impacts)
- III. Managerial considerations by category
  - A. Organism
  - B. Environment
  - C. Physical description

PROFILE OF AN OIL SPILL

An extract from the TSNL International Base Line Data Coding System (IBLDCS)

INTRODUCTION: The IBLDCS Master Outline, the coding system for regional inventorying of field data records, is described more fully on page 8. When all the references concerning a particular topic are assembled from the master outline in sequence, a complete description or "profile" of that topic or species is the result.

DESCRIPTION: The oil spill profile consists of factors which must be addressed in order to evaluate the impact of an oil spill. Naturally a small spill will affect only a few factors, while a large spill may affect them all. Many of the factors are directly affected by oil (water quality, biological organisms, etc.) and many other factors are secondary or tertiary effects (strains on the tax base, induced psychological stress, etc.). A related profile which could be valuable would be the converse profile, factors which affect oil spills. This would show a two-way relationship in many cases. For example oil affects bacteria and bacteria affect the oil.

USES: When stored in an automated system, the oil spill profile or the species profiles do not exist as separate entities, but are integrated into the total data base. When one is interested in a particular topic such as oil spills, the data base can be queried for that particular profile. The request might be, for instance, to list, for each oil spill factor, the agencies, organizations, or individuals whose data has been filed under that category. For a legal assessment of oil spill damages one would also recall information on the type of study which generated the base line data, and whether this study is ongoing or completed. Such a search capability is an effective tool for determining overall funding priorities.

Such a review would reveal gaps in the data, areas where perhaps no work has been done at all, but where works needs to be done.

DAMAGE ASSESSMENT: A complete oil spill damage assessment will consist of comparing the data base which describes all these factors for a region with the sampling and inventory data taken during and after the period of peak oil spill activity.

When the sampling and inventory data is entered into the data base, the computer can be instructed to compare the situation before and after the spill to spot potential problem areas. If it was seen, for example, that the shrimping industry might be adversly affected, the shrimp profile could be pulled and correlated with the oil spill profile using the new data to assess the potential impact. If tourism was under discussion, a profile for man, the tourist, can be developed including such aspects as sportsfishing, beaches, tourism related business, development, and investments.

This powerful tool works only because of the comprehensive nature of the Master Outline.

TSNL
January, 1980

OIL SPILL PROFILE

Extracted from the TSNL Master Outline for Regional Inventories

A. Physical aspects
  I. Meteorological
  II. Hydrological and Hydrogeomorphic
    E. Estuary/bay system
      3. Water quality
        b. Cation concentration
        c. Anion concentration
        d. Salinity
        e. Specific conductance
        f. pH
        g. Turbidity
        h. Transparency
        i. Nutrients
          1) Carbon
      4. Hydrodynamic relationships
        f. Erosion
          1) Shoreline
        g. Deposition
          1) Shoreline accretion
          2) Sedimentation
  III. Geological
    F. Environmental
      1. Active processes
        d. Erosion and accretion
      2. Engineering properties
        b. Cohesion
        d. Density
        f. Infiltration/runoff
      3. Biogeochemistry
      4. Land Resource
      5. Land use
        a. Capability
        b. Classification
  IV. Pedological
    C. Description
      1. Physical characteristics
        d. Texture
        f. Consistence
        j. Penetrability
        k. Permeability
        r. Aggregate stability
        u. Porosity (%)
      2. Soil hydrology
        a. Soil moisture content
        f. Maximum water holding capacity
        i. Runoff
        j. Hydraulic conductivity
        k. Infiltration rate
      3. Chemical characterization
        a. Elemental
          1) Ion concentration
          3) Total carbon
        b. Organic compounds
        f. Wastes and pollutants
      5. Effects of physical interaction
        a. Abiotic
          2) Chemical
        b. Biotic
          1) Mechanical
            c) Human
              v. Mining/quarrying
          2) Chemical
            c) Human
              iv. Petroleum effluents
    D. Use capability
      3. Engineering uses
        a. Suitability
        b. Degree of limitation
  V. Chemical
    C. Carbon cycle
      2. Aquatic
    D. Other geochemical cycles
    E. Dissolved oxygen - aquatic
    F. Chemical oxygen demand - aquatic
    G. Biochemical oxygen demand - aquatic
    H. Atmospheric gasses
      1. Gaseous pollutants
      2. Gaseous nonpollutants
    I. Total particulates
      1. Aquatic
      2. Airborne
    O. Petroleum

B. Biological aspects
  I. Taxonomic classification
    A. Viruses
    B. Superkingdom Prokaryonta
      Division 1. Cyanobacteria
      Division 2. Bacteria
    C. Superkingdom Eukaryonta
      Kingdom 1. Myceteae (Fungi)
        Division 1. Gymnomycota
        Division 2. Mastigomycota
        Division 3. Eumycota
      Kingdom 2. Plantae (Phyta)
        Division 1. Chlorophycophyta
        Division 2. Euglenophycophyta
        Division 3. Charophyta
        Division 4. Phaeophyceae
        Division 5. Rhodophycophyta
        Division 6. Chrysophycophyta
        Division 7. Pyrrhophycophyta
        Division 8. Cyanochloronta (Cyanophyta)
        Division 9. Schizonta (see B.D-2)
        Division 10. Myxomycota
        Division 11. Eumycota (see C.K-1.D-3)
        Division 22. Magnoliophyta (Anthophyta)
      Kingdom 3. Animalia (Zoa)
        Phylum 1. Protozoa
        Phylum 2. Porifera - sponges
        Phylum 4. Cnidaria (Coelenterata)
        Phylum 5. Ctenophora
        Phylum 6. Platyhelminthes - flatworms
        Phylum 7. Mesozoa
        Phylum 8. Rhynchocoela (Nemertina) - proboscis worms
        Phylum 9. Gnathostomulida
        Phylum 10. Rotifera - rotifers
        Phylum 11. Gastrotricha
        Phylum 12. Kinorhyncha (Echinodera)
        Phylum 13. Nematoda - roundworms
        Phylum 14. Nematomorpha - hairworms
        Phylum 15. Acanthocephala
        Phylum 16. Priapulida
        Phylum 17. Sipuncula - peanut worms
        Phylum 18. Mollusca
        Phylum 19. Echiura
        Phylum 20. Annelida - segmented worms
        Phylum 21. Pogonophora
        Phylum 22. Tardigrada - water bears
        Phylum 24. Arthropoda
        Phylum 26. Phoronida
        Phylum 27. Bryozoa (Ectoprocta) - bryozoans
        Phylum 28. Entoprocta
        Phylum 29. Brachiopoda - lamp shells
        Phylum 30. Chaetognatha - arrowworms
        Phylum 31. Echinodermata
        Phylum 32. Hemichordata - acorn worms
        Phylum 33. Chordata
  II. Ecological classification
    C. Habitat
      1. Marine
      2. Estuary/bay
      3. Saline marsh
      5. Coastal dune complex
    D. Abiotic interactions
      4. Meteorological data
        a. Physical
          5) Solar radiation
      5. Hydrological data
        a. Physical
          3) Water turbidity
          10) Solar radiation
        b. Chemical
          10) Pollutants
        c. Biological
          1) Organic matter
          2) Bacterial content
      6. Pedological data
        a. Physical
          8) Permeability
          9) Penetrability
        c. Chemical
          1) pH
          9) Other
        e. Biological
          1) Organic matter

II. Ecological classification (continued)
  F. Biotic/cultural interactions
    1. Between species
      b. Environmental perception and world view
        1) Environmental perception
          a) Perception determinants
          b) Evaluative criteria
          c) Problem areas
            i. Biophysical
            ii. Recreational
            iv. Jobs
            vi. Health
            viii. Hazards
              i) Natural
              ii) Man-made
          d) Attitude intensity scale
            i. Biophysical
            ii. Recreation
            iv. Jobs
            vi. Health
            viii. Hazards
          h) Attitudes of decision makers
            i. Biophysical
            ii. Recreation
            iv. Jobs
            vi. Health
            viii. Hazards
          i) Governmental guidelines
            i. Federal
            ii. State
            iii. Local
        2) World view
  G. Cultural interactions
    2. Within group interactions
      b. Non-material culture
        1) Sociocultural aspects
          a) Social subsystem
            xv. Quality of life
              i) Aesthetics
              ii) Leisure
                i] Recreation
                  viii/ Vacations
                  ix/ Recreational facilities
                  x/ Parks
                  xi/ Other
            xvi. Social problems
              i) Disasters
          b) Economic subsystem
            i. Economic organization
              i) Agriculture, forestry and fishing
              vii) Retail trade
              viii) Finance, insurance, real estate
              ix) Services
              x) Public Administration
            iii. Food supply
            viii. Waste and pollution
            ix. National/regional economic development
          c) Political subsystem
            iii. Governmental activities
              ii) Public finance
              iii) Public works
              iv) Research and development
              vii) Public welfare
              ix) Miscellaneous government activities

Appendix A: Capital resources inventory
  I. Natural resources
    B. Water
    C. Land
    E. Energy
      1. Chemical bond
        a. Petroleum
        c. Natural gas
  II. Utilization of resources
    A. Agriculture, forestry and fishing
      5. Fishing, hunting and trapping
    B. Mining
      4. Oil and gas extraction
    G. Retail trade
    H. Finance, insurance, and real estate
    I. Services
    J. Public administration
  III. Limiting factors
    A. Natural pressures
      1. Geophysical
        b. Hydrologic
        c. Geologic and geomorphic
    B. Man-made pressures
      1. Environmental stress phenomena
        c. Resource extraction
        e. Land alteration
        f. Resource renewal
      2. Human stress phenomena
        a. Physical
          4) Visual
        b. Economic
        f. Governmental
          1) Laws
          2) Regulation
          3) Taxation

Appendix B: Management concerns
  I. Managerial interests by industry
    A. Industry
      3. Fishing and hunting
      7. Trade - wholesale
      8. Trade - retail
      9. Transportation
      12. Services
      13. Finance
      14. Insurance
      15. Real estate
  II. Interests by project and activity
    B. Activities
      4. Resource extraction
      8. Waste emplacement, treatment, disposal
      9. Chemical treatment
      10. Accidents
  III. Managerial considerations by category
    A. Organism
      2. Bacteria
      3. Plants
      4. Animals
        a. Fish and wildlife
          1) Commercial
          2) Sport
          3) Rare and endangered
    B. Environmental
      1. Physical
        a. Air
        b. Water
          1) Water quality
          3) Toxic substances
          5) Areas of high natural productivity or essential habitat
          6) Hazards
          7) Visual blight
        c. Land
          1) Land resources
            b) Soils
          2) Land use/land capability
          3) Areas of high natural productivity or essential habitat
          4) Areas of unique, scarce, fragile, or vulnerable natural habitats or physical features, including wild and scenic areas
          5) Areas of recreational value
          6) Areas of cultural value, including historical features and archaeological sites
          8) Toxic substances
          9) Hazards
          10) Visual blight

Major parameters considered applicable to TSNL fish/shrimp species profiles

I. Base Information: Biological Aspects
II. Ecological classification
A. Evolutionary history
B. Distribution
C. Habitat
D. Abiotic interactions
4. Meteorological data
a. Physical
5. Solar radiation
6. O_2 partial pressure
5. Hydrological
a. Physical
1) Water depth
2) Water temperature
3) Water turbidity
4) Current speed
5) Current volume
6) Current direction
7) Tidal phase
b. Chemical
1) Dissolved oxygen
6) Salinity
7) pH
13) Herbicides and pesticides
14) Toxic substances
15) Other
E. Biotic interactions (and adaptations for interactions)
1. Intraspecific
a. Reproduction
4) General reproductive strategy
a) Reproductive attempts/lifetime
b) Age at reproduction
c) Attempts/year
d) Effort/reproductive attempt
i. Offspring number
ii. Size-weight ("value")/offspring
iii. Eggs/female
5) Reproductive phenology and location
b) Mating
i. Time
ii. Site
iii. Artificial propagation
b. Development and maintenance of life stages (varies with taxon)
4) Adult
a) Morphology and physiology
iii. Nutrient requirements/utilization
b) Energetics
i. Productivity
viii. Growth rate
c) Spatial factors
i. Mobility
ii. Space utilized
i) Bottom-dwelling
ii) Surface-dwelling (aquatic)
iii) Buried/underground
vii) Territoriality
viii) Migratory habits
d) Chronological factors
i. Life span/longevity/length of phase
ii. Innate rhythms
i) Circadian
ii) Diurnal
c. Population parameters
1) Birth rate
2) Mortality (rate and causes)
3) Rate of recruitment
2. Interspecific
a. Individual
1) Nutritional source (food)
2) Predators
3) Parasites
4) Competitors
5) Symbionts
a) Commensalism
b) Protocooperation
c) Mutualism
6) Epiphytes
b. Community
1) Trophic level
a) Autotroph
b) Heterotroph
2) Succession
3) Relative abundance
a) Capture records
b) Catch/unit effort
4) Contributions to the community
a) Habitat modifications
b) Matter/energy transfer
i. Products
ii. Pathway (nutrient cycles)
c) Other
5) Associated species
F. Biotic/cultural interactions
1. Between species
a. Interactions with man (positive and negative)
1) Diet
b) Vertebrates
i. Food
3) Aesthetics
b) Vertebrates
ii. Sport and tourism
i) National parks
ii) Wildlife refuges
iii) Other
4) Health/medical
b) Vertebrates
i. Disease
ii. Parasites
iii. Poisons
iv. Allergens
v. Drugs
i) Antibiotics
ii) Other
vi. Other
5) Status
a) Legal
i. Rare
ii. Endangered
iii. Threatened
iv. Other
b) Actual
i. Rare
ii. Endangered
iii. Threatened
iv. Other
c) Causes
i. Rare
ii. Endangered
iii. Threatened
iv. Other
b. Environmental perception and world view
1) Environmental perception
a) Perception determinants
i. Culture
ii. Income
iii. Educational level (%)
iv. Other
b) Evaluative criteria
i. Kluckhohn model
i) Man subject to nature
ii) Man with nature
iii) Man over nature
iv) Man within nature
c) Problem areas
i. Biophysical
ii. Recreation
iv. Jobs
vi. Health
viii. Hazards
i) Natural
ii) Man-made
ix. Other
d) Attitude intensities scale
i. Biophysical
ii. Recreation
iv. Jobs
vi. Health
viii. Hazards
ix. Other
e) Activities (involvement) index
i. General issues
ii. Local issues
f) Cognitive dissonance
i. Stated interests (1-9)
ii. Actual behavior (1-9)
f) Identification of perceived decision-makers
i. Elected officials
ii. Planners
iii. Scientific/technical experts
iv. Local residents
v. Other
h) Attitudes of decision-makers
i. Biophysical
ii. Recreation
iv. Jobs
vi. Health
viii. Hazards
ix. Other
i) Other
i. Governmental guidelines
i) Federal
ii) State
iii) Local
ii. Existing models
2) World view
G. Cultural interactions
2. Within group interactions
b. Non-material culture
1) Sociocultural aspects
b) Economic subsystem
i. Economic organization (SIC)
i) Agriculture, forestry and fishing
iv) Manufacturing
vi) Wholesale trade
vii) Retail trade
viii) Finance, insurance, real estate
ix) Services
ii. Trophic levels
i) Exploitative and producer activities
ii) Consumer activities
iii. Food supply
iv. Land use
vi. Exchange and marketing
vii. Labor and employment
viii. Waste and pollution
ix. National regional economic development
x. Other
c) Political subsystem
iii. Government Activities
iv) Research and development
v) Government enterprises
vi) Government regulation
ix) Miscellaneous government activities
iv. Public policy (foreign, social, economic
i) Political attutudes
ii) Political socialization

BIOLOGICAL ASPECTS RELATING TO THE IXTOC I OIL SPILL

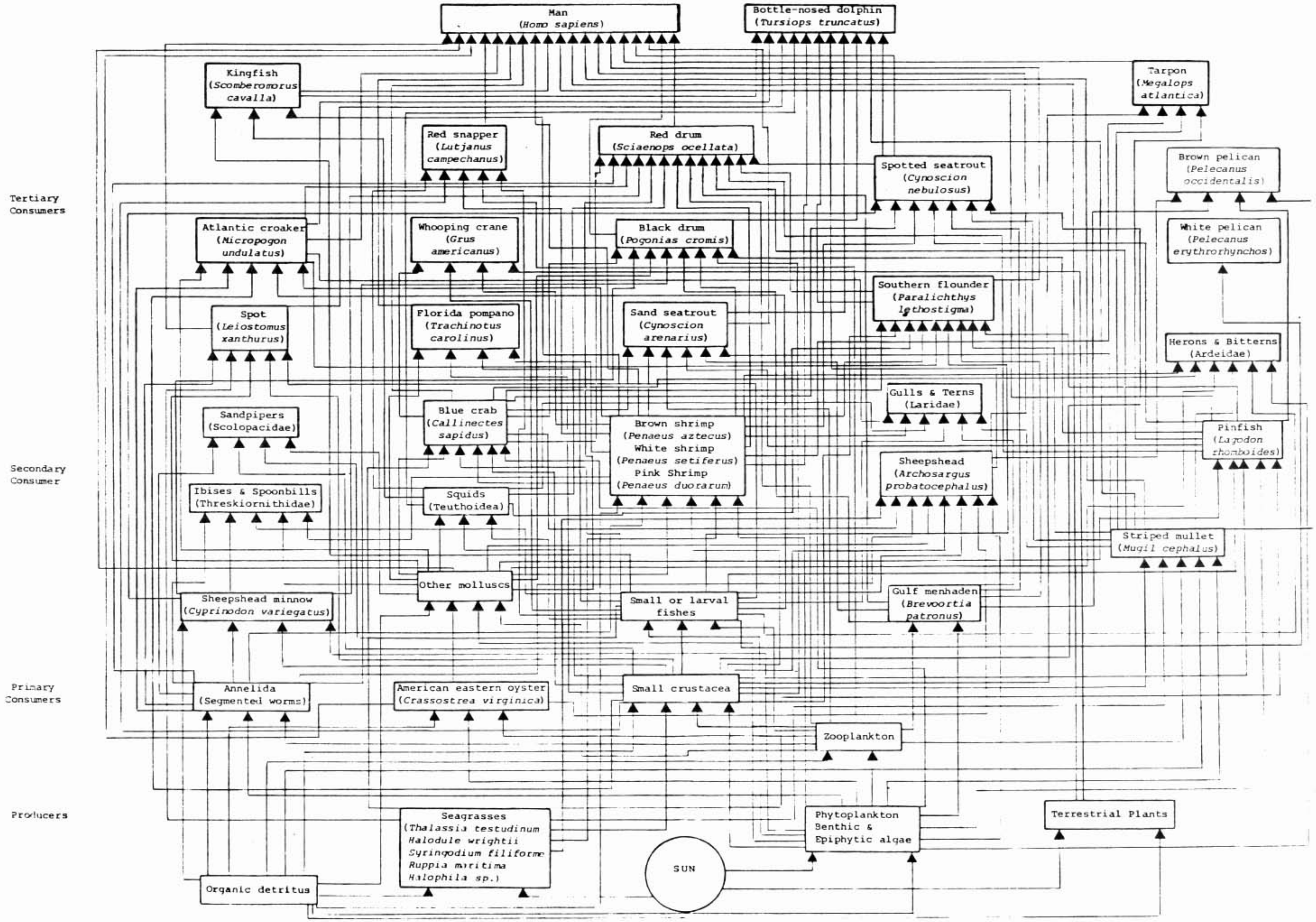
The following assembled materials review the biological information pertinent to an understanding of the possible effects of the Ixtoc I oil spill on the ecology of the Texas Gulf coast. Included are: a diagram of the trophic relationships of important species; a chart relating the spawning patterns of these species; individual species accounts revealing general temporal and spatial distributions and concentrations; a comprehensive list of South Texas Gulf coast fishes; a table of commercial fish landings from Texas coastal waters; and a review of the known effects of oil on biological systems.

It has been necessary to choose only the most relevant data on a selection of the most important species. Many species that occur in the Gulf region have been omitted to make this report more comprehensible. Complete lists of algae and molluscs for the entire Gulf coast along with distribution and habitat records, are available at TSNL. Also available is a nearly complete list of all other Gulf coast organisms.

Although oil pollution is a relatively new problem, entire monthly journals are devoted to its study and, each year, the amount of published literature on the subject has shown an amazing proliferation. To review all of the literature is therefore impossible, and only certain references have been chosen. Other review papers have been utilized to some extent. A complete bibliography for this report is available from TSNL.

Figure 1. FOODWEB CHART
NORTHWESTERN GULF OF MEXICO
TEXAS COASTAL ZONE

Figure 1 represents a small portion of the food web dealing primarily with the region encompassing the South Texas coast. Arrows follow the direction of the producer-consumer or prey-predator relationships, always advancing towards successively higher trophic levels. The sun is also included due to its role as the primary energy source for the photosynthetic processes carried out by the producers.



Tertiary Consumers
Secondary Consumer
Primary Consumers
Producers
Man (Homo sapiens)
Bottle-nosed dolphin (Tursiops truncatus)
Kingfish (Scomberomorus cavalla)
Tarpon (Megalops atlantica)
Red snapper (Lutjanus campechanus)
Red drum (Sciaenops ocellata)
Spotted seatrout (Cynoscion nebulosus)
Brown pelican (Pelecanus occidentalis)
Atlantic croaker (Micropogon undulatus)
Whooping crane (Grus americanus)
Black drum (Pogonias cromis)
White pelican (Pelecanus erythrorhynchos)
Southern flounder (Paralichthys lethostigma)
Spot (Leiostomus xanthurus)
Florida pompano (Trachinotus carolinus)
Sand seatrout (Cynoscion arenarius)
Herons & Bitterns (Ardeidae)
Gulls & Terns (Laridae)
Sandpipers (Scolopacidae)
Blue crab (Callinectes sapidus)
Brown shrimp (Penaeus aztecus)
White shrimp (Penaeus setiferus)
Pink Shrimp (Penaeus duorarum)
Pinfish (Lagodon rhomboides)
Sheepshead (Archosargus probatocephalus)
Ibises & Spoonbills (Threskiornithidae)
Squids (Teuthoidea)
Striped mullet (Mugil cephalus)
Other molluscs
Sheepshead minnow (Cyprinodon variegatus)
Small or larval fishes
Gulf menhaden (Brevoortia patronus)
Annelida (Segmented worms)
American eastern oyster (Crassostrea virginica)
Small crustacea
Zooplankton
Seagrasses (Thalassia testudinum Halodule wrightii Syringodium filiforme Ruppia maritima Halophila sp.)
Phytoplankton Benthic & Epiphytic algae
Terrestrial Plants
SUN
Organic detritus

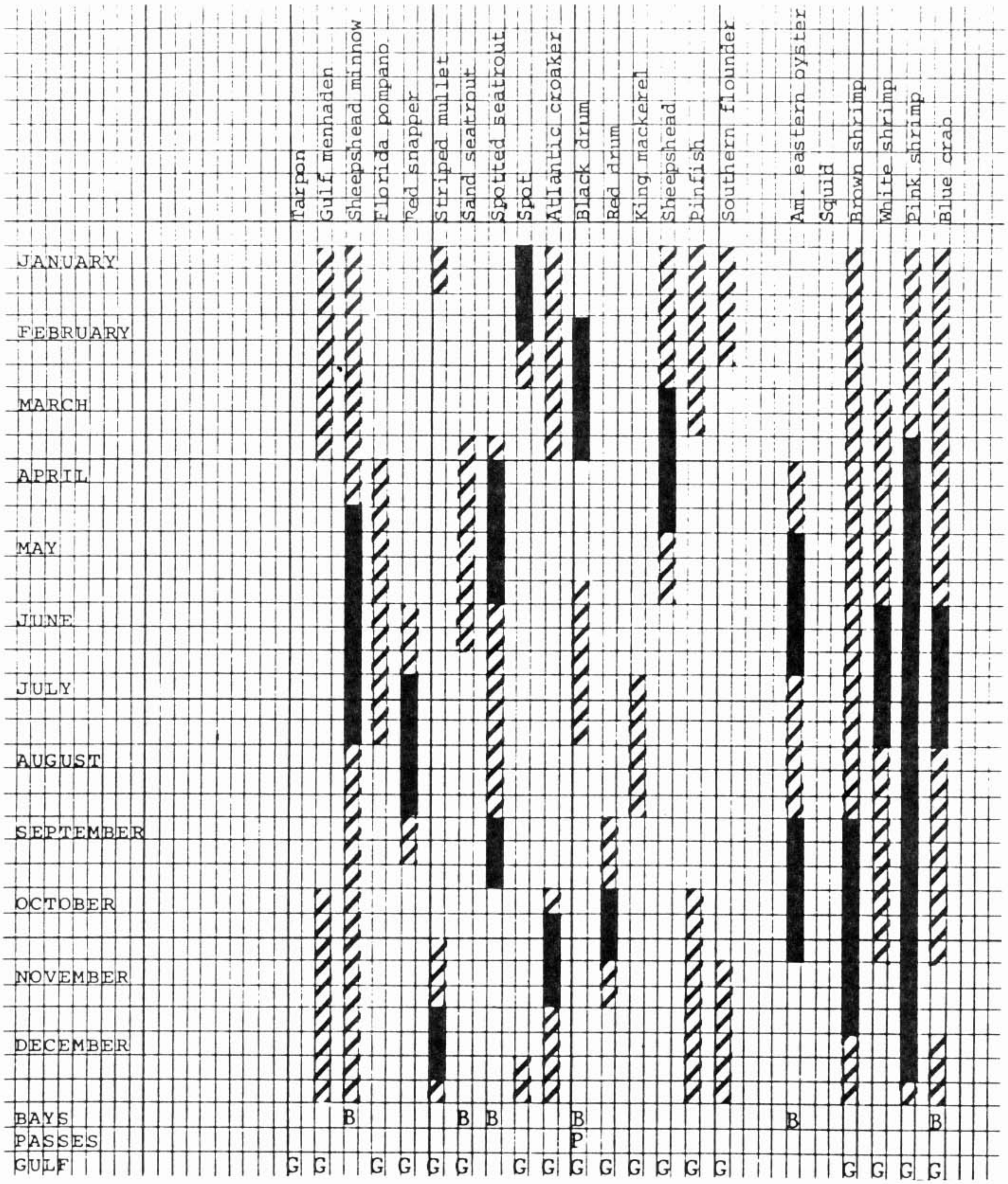
FOOD WEB

Figure 1 represents a small portion of the food web found within the great expanse of the Gulf of Mexico. The purpose of such an illustration, with respect to possible damage to one or any number of the given organisms by oil, becomes apparent when the impact throughout the food web of such an occurrence is examined. The figure, in addition to providing insight into interspecific trophic relationships, also establishes an hierarchy whereby, at a glance, one can estimate the approximate trophic level occupied by any given species, i.e. producer, primary consumer, secondary consumer, tertiary consumer, as well as intermediate levels. Most of the organisms included on the chart were chosen from those which were considered to be most valuable to man from a commercial, recreational or aesthetic standpoint. However, many of the taxonomic groupings, as well as some of the individual species, were included solely as an aid in understanding the food web as a whole. Some possibly significant species or groups have been excluded due to the limited amount of information available as well as the need to limit the scope of such a project. It is for this reason that amphibians and reptiles, as well as small land mammals, were excluded, in spite of their importance to the diet of many of the shorebirds. Each of the arrows on the chart represents data extracted from one or several different references. Omitted arrows, where one might, in fact, expect trophic relationships to exist, have resulted from the lack of sufficient documentation within the researched literature to support their inclusion. Man and the bottle-nosed dolphin were placed at the head of the figure since neither is severely threatened by any known predator and both reach a larger adult size than most of the fishes found below them in the hierarchy. However, man's role as an omnivore is also considered with the addition of terrestrial plants as a food item.

Although it might seem somewhat tedious to attempt tracking down all of the trophic relationships involving a given species by following the lines, the value of such a figure lies more in its ability to present the information as it relates to the food web as a whole rather than simply as one small piece of data. As an example, one can readily see the large concentration of lines leaving the centrally located shrimp species which, in turn, can be interpreted as demonstrating their greater relative value to the stabilization of the food web as a whole. However, the exclusion of the white or brown pelican could be seen as having less of an obvious impact on the other species found within the web.

In several cases, such as with the croaker, kingfish (king mackerel), red snapper and spot, reference to an item in the diet consisting of "fish" was slightly modified and represented by the category "small or larval fishes" due to the lack of a separate category which included adults. The obvious cases of cannibalism found within the larger groups such as molluscs and crustaceans as well as among the individual species were not included.

Figure 2. TEMPORAL AND SPATIAL REPRESENTATION OF SPAWNING CHARACTERISTICS AMONG IMPORTANT SPORT AND COMMERCIAL FISHES AND INVERTEBRATE SPECIES ALONG THE SOUTH TEXAS COAST



Possible spawning period

Peak spawning period

SPAWNING ACTIVITY

Figure 2 is provided to enable the speedy determination of spawning time and site for those species mentioned as the most valuable sport and commercial fishes and shellfishes of the Texas coast. Due to the increased susceptibility of the larval stages of most organisms to the toxic effects of oil (Sanborn, 1977), such a determination is necessary when assessing possible damage to a given population or species group.

The months of the year, listed down the left column, are divided into thirds representing approximate 10-day periods to enable a more precise representation of spawning time. As indicated in the key, cross-hatching is used to indicate possible spawning time, while the darkened portions represent peak spawning periods as determined through the literature. Often a given period is representative of the cumulation of data from several different sources and may not refer to any one statement. This was necessary since authors quite often differ with respect to the beginning and cessation dates for the respective spawning periods. Spawning sites are indicated using the letters B, P and G referring, in that order, to the bays, passes and the Gulf of Mexico. Fish and invertebrate species have been listed in taxonomic sequence (down to order) which facilitates comparison of this figure with the species synopses which follow.

SPECIES ACCOUNTS

In an attempt to provide the additional information needed to establish the temporal and spatial distributions and concentrations of those fishes and invertebrates found in Figure 2, the following short synopses were assembled. Information with regard to preferred habitats, migrational patterns, relative abundance, as well as additional reproductive information not included in Figure 2, is provided. Following the species accounts, a comprehensive list of fishes of the South Texas coast, as well as offshore forms, has been included. This, as well as more specific distributional information by bay system, can be found in the TSNL publication Fishes of Coastal Texas. Table I, a compilation of previously published Texas Parks & Wildlife Commercial Fish Landings reports, has also been included listing yearly averages for both Gulf and bay commercial landings in both pounds and dollars for the six year period beginning in September 1972 and terminating in August 1978.

TARPON - *Megalops atlantica*

Although tarpon populations have declined in numbers since they were first fished along the Texas coast, in recent years they have made a comeback and have begun to reappear moving up and down the coast as previously reported (Dutch, 1975). The reason for their temporary absence has not yet been determined, although some say it might have been due to the generalized increase in pollutants of the area (Dutch, 1975). Tarpon prefer coastal marine areas, often entering brackish water and sometimes rivers (Knapp, 1953; Jones, Martin, and Hardy, 1978). Movements along shore coincide with spring migrations of the silverside mullet, a preferred food item, along the lower coast (Dutch, 1975). Very little is known of their spawning activity along the Texas coast.

GULF MENHADEN - *Brevoortia patronus*

Gulf menhaden are very abundant along the Texas coast, moving into the bays through the passes as young, from winter until early spring, after which many emigrate back to the Gulf in the fall (TPWD, 1978). Menhaden are strictly surface forms (Hoese, 1965) relying heavily on a planktonic diet. Though of little value as a sport fish (TPWD, 1978) they are relatively important as food to many of the commercial fishes of greater interest to man. The eggs are buoyant (James, Martin, and Hardy, 1978) and are found from the beaches to offshore (Hoese, 1965; TPWD, 1978) from midwinter to early spring (Gunter, 1945; Miller, 1965).

SHEEPSHEAD MINNOW - *Cyprinodon variegatus*

These small fish can be found mostly in shallow salt marsh areas bordering on Texas bays (Gunter, 1950; Moore, 1958; Strawn and Dunn, 1967; Hoese and Moore, 1977). Having the greatest salinity tolerance of any known fish, they often inhabit extreme environments (Hoese and Moore, 1977; Hardy, 1978a). Movements are usually restricted to migrations towards warmer and slightly deeper water in the fall (Gunter, 1945) although Hardy (1978a) mentions limited inshore and offshore movements in April, May and November on the Texas coast. Hardy (1978a) also states that the fish tend to enter bayous during the colder months and bays during the warmer periods. Peak abundance seems to occur during the winter and spring (Gunter, 1945; TPWD 1975b; Johnson, 1977). The eggs of the sheepshead minnow are "demersal, adhesive or semi-adhesive, sticking to plants, stuck to each other, or at times partially buried in the bottom" (Hardy, 1978a). Spawning takes place in the shallow areas of bays, large tidepools, mangrove lagoons, and pools, over bottoms of sand, black silt, or mud (Hardy, 1978a).

FLORIDA POMPANO - *Trachinotus carolinus*

The Florida pompano inhabits primarily the Gulf beach surf zone (Reid, Inglis, and Hoese, 1956; McFarland, 1963; Pew, 1966; Hoese and Moore, 1977) although large fish are sometimes found within the bays (Gunter, 1944). Peak abundance of young pompano occurs in the summertime during

July, August, and September (Gunter, 1945) with fewer numbers reported during the winter months (Johnson, 1978). Although little information on migration patterns in the Gulf of Mexico exists, the eastern Atlantic population appears to move northward during the spring and summer (Johnson, 1978). The Florida pompano is considered by many the most delicious of all fishes (Pew, 1966).

RED SNAPPER - *Lutjanus campechanus*

In recent years the red snapper has become one of the most sought after sport fishes of the Gulf coast (Moseley, 1965). Considered a reef dwelling species, most individuals occur in the offshore Gulf (TPWD, 1978). Commercial data indicate that adults are not strictly confined to irregular or hard bottoms (Moseley, 1965) and juveniles, in fact, are usually found widely distributed over muddy and sandy bottoms (Moseley, 1965; TPWD, 1978). Spawning probably occurs offshore with some "inshore transport of larvae and juvenile stages" (Moseley, 1965). Although definite migrations have not been substantiated, some offshore movements in the winter and inshore movements in the summer have been observed (Hardy, 1978b). It has also been suggested that "as snappers grow they seek deeper water" (Moseley, 1965). Declining landings in recent years may be an indication of declining populations (Arnold, et al., 1978).

STRIPED MULLET - *Mugil cephalus*

One of the truly euryhaline fishes, the striped mullet is found in nearly all environments from fresh water rivers to hypersaline flats and shallows (Gunter, 1945; Reid, Inglis, and Hoese, 1956; Hoese and Moore, 1977; TPWD, 1978). During the ebb tide at night they are known to concentrate in large numbers along the shallow waters adjacent to beaches (Reid, Inglis, and Hoese, 1956; Fuls, 1974). Migrations consist of adults leaving the bays in large schools in the fall to spawn (Gunter, 1945; McFarland, 1963; TPWD, 1975f) and a return of smaller schools to the bays over a six-month period (Hoese and Moore, 1977). The larvae hatch from floating eggs although "some sinking of viable eggs" has been documented (Martin and Drewry, 1978). The young then migrate to the bays soon afterwards (TPWD, 1978). The striped mullet is one of the most abundant organisms in South Texas in both numbers and biomass (Hellier, 1961; McFarland, 1965; Moore, 1974; Hoese and Moore, 1977). They thus form a major link in the food web providing many of the marine carnivores with an abundant nutrient source.

SAND SEATROUT - *Cynoscion arenarius*

Although not especially abundant, the sand seatrout has become a significant sport fish along the Texas coast. It occurs in greatest numbers in the bays during the late summer and fall (Pew, 1966) with an abundance peak in the Gulf in December and January (Gunter, 1945; Parker, 1965; TPWD, 1975e). Gulfward migrations take place "only during cold weather" (TPWD, 1978). Spawning occurs in the deeper areas of the bays or the shallow Gulf, the young remaining over muddy bottoms (Hoese and Moore, 1977).

SPOTTED SEATROUT - *Cynoscion nebulosus*

Considered the "most sought after, most often caught sport fish on the coast" (TPWD, 1978), the speckled trout frequents bays and the shallow Gulf areas. Both adults and juveniles seem to prefer areas over dense vegetation, particularly *Thalassia* beds (Zimmerman, 1969; Johnson, 1978). Spawning occurs mostly at night in the deeper areas of the bays and lagoons (TPWD, 1975a; TPWD, 1975f; Hoese and Moore, 1977; Johnson, 1978). The eggs are initially buoyant becoming demersal after twelve hours and hatching after about forty hours (Johnson, 1978). The young remain in or near bottom vegetation (Hoese and Moore, 1977) seemingly preferring the "shell rubble of channel bottoms and the edges of grass flats" (Johnson, 1978). Migrations are limited to general gulfward movements as temperatures decline, the extent of movement usually depending on the severity of the winter (Stevens, 1978). Some fish actually enter the Gulf, although many simply seek out the deeper bay waters. During the warmer months the fish return to the inland bay areas. Sometimes a rapid decrease in salinity will cause them to seek out other areas (TPWD, 1975a). Although abundant year-round, the speckled trout is seen in greatest numbers during the warmer months (Parker, 1965; TPWD, 1975e).

SPOT - *Leiostomus xanthurus*

A very common bay and shallow Gulf species (Hoese and Moore, 1977), the spot seems to prefer mud and sand bottoms although as juveniles they are also quite abundant in *Thalassia* beds (Zimmerman, 1969; Johnson, 1978). Since spawning generally occurs in the Gulf near the passes, the young spread rapidly into the bays (Gunter, 1945). As the young fish mature they gradually move towards deeper water (Hoese & Moore, 1977) where they remain in the shallower lagoons and coves until temperatures drop, when they move to the deeper waters of the bays and Gulf (Johnson, 1978). Although very abundant in Texas bays throughout the year, they can also be found during the fall spawning season in the Gulf (TPWD, 1978).

ATLANTIC CROAKER - *Micropogon undulatus*

The Atlantic croaker is usually found over mud, sand, mud-sand mixtures, mud-shell mixtures and over "live" bottoms of mud-sand mixtures in the bays during the warmer months (Johnson, 1978). During the fall (September and October) adults migrate to the Gulf to spawn and remain there while the young return to the bays. Juveniles can tolerate colder temperatures better than the adult fish and thus remain in the upper reaches of the estuaries throughout the winter while most adults remain offshore (Johnson, 1978). Considered perhaps the "commonest bottom-dwelling estuarine species" (Hoese and Moore, 1977) the croaker is also spoken of as the most abundant individual species of food fish in the bays (TPWD, 1978).

BLACK DRUM - *Pogonias cromis*

The black drum seems to prefer the shallow waters of the bays (TPWD, 1975f; Hoese and Moore, 1977) and is most often found over sandy bottoms (Johnson, 1978). Nursery grounds usually occur in shallow vegetated regions (TPWD, 1975a) most often in muddy waters (TPWD, 1975f). Besides the pronounced spawning migrations towards the passes which occur in late winter and early spring, a period of heavy runoff can also initiate temporary movements into freshwater streams (Simmons and Breuer, 1962). The highest concentrations of the black drum are usually found in Corpus Christi Bay and the Laguna Madre (Simmons and Breuer, 1962). Peak abundance off Texas occurs from October through February (Johnson, 1978).

RED DRUM - *Sciaenops ocellata*

Adult redfish are usually solitary, living in the shallower waters of the bays (Hoese and Moore, 1977). Spawning migrations occur in the fall with actual spawning taking place in the Gulf near passes and channels (Johnson, 1978). The young immediately enter the bays (TPWD, 1978) where they seek out "clumps of grass or oyster shell over slightly muddy bottoms in quiet protected waters" (Johnson, 1978). These smaller fish usually remain in the bays even during the winter months (TPWD, 1978). In contrast, some of the largest redfish may stay offshore instead of returning to the bays in the spring as the young or other spawning adults do (Hoese and Moore, 1977). Thus, redfish movements can be characterized as either "broad random movements, loosely coordinated temperature migrations, or strong offshore migrations" (TPWD, 1975f).

KING MACKEREL - *Scomberomorus cavalla*

Although more common in deep clear water (Pew, 1966; Causey, 1969), the king mackerel has also been found to inhabit murky areas (TPWD, 1978). Off of Galveston, Freeport, and Port Arthur they are known to "congregate in large numbers around reefs" (Pew, 1966). These fish migrate in large schools along the Gulf coast throughout the summer months (Pew, 1966; TPWD, 1978), and their appearance is regarded by some as "the marine harbinger of summer" (Hoese and Moore, 1977). Very popular as an offshore sport fish it is often considered as the "very backbone of the offshore sport fishing along the Texas coast" (TPWD, 1978).

SHEEPSHEAD - *Archosargus probatocephalus*

Both adult and juvenile sheepshead seem to prefer vegetated areas such as *Thalassia* beds (Zimmerman, 1969) or other protected areas where shelter is abundant (TPWD, 1975f; TPWD, 1978). Adults, specifically, can be found frequenting "oyster beds and muddy shallow waters, particularly about inlets near piers, breakwaters, wrecks and often up rivers" (Johnson, 1978). Spawning occurs in the Gulf "near jetties, rock piles and reefs" (TPWD, 1978). The young hatch from floating eggs (TPWD, 1975f; Johnson, 1978) and enter the bays from late winter to early spring (TPWD, 1975f). Peak occurrence in the Upper Laguna Madre is from December to March (TPWD, 1975e) while in Galveston Bay it is during the months of May, June, July, and October (TPWD, 1975f).

PINFISH - *Lagodon rhomboides*

According to Reid, Inglis, and Hoese (1956) there exists a "high degree of association between this species and vegetated areas". Although the adults "prefer open waters as opposed to estuaries", vegetation is still the most important variable in habitat choice (Johnson, 1978). If vegetation is absent they seek some other form of shelter such as "rocks, pilings, etc." (Johnson, 1978). Pinfish migrate towards the Gulf in late summer and fall culminating in a late fall and winter spawning well offshore (Hoese, 1958; Miller, 1964; Cameron, 1969). It has been suggested by Cameron (1969) that perhaps this winter spawning is an adaptation to the grasses growing in the spring, for, from March to April, population levels increased sharply due to the influx of large numbers of juveniles into the grassflats (Zimmerman, 1969). These migration patterns are thus likely responsible for the peak abundance levels in the *Thalassia* beds during the spring, summer, and early fall and the lows during the late fall and winter (Zimmerman, 1969).

SOUTHERN FLOUNDER - *Paralichthys lethostigma*

Adult southern flounder are usually found within the bays and shallow Gulf (Hoese, 1958) over "softer mud bottoms" (Hoese and Moore, 1977). The juveniles are found in shallow bay areas sometimes venturing into lower salinities (Knapp, 1953; Hoese and Moore, 1977) and apparently avoid areas of high turbidity (TPWD, 1975a). Spawning migrations take place in the Gulf of Mexico during the fall (Stokes, 1975; TPWD, 1975f; Hoese and Moore, 1977; TPWD, 1978). Mass migrations can be triggered by a severe norther initiating this exodus out of the bays (Hoese and Moore, 1977). Young flounder begin to enter the estuaries in late winter and spring (Stokes, 1975; TPWD, 1975b; TPWD, 1975f; Johnson, 1977). The adults also return in the spring but more gradually than the fall outflux (Stokes, 1975). Johnson (1977) states that the southern flounder is "possibly the most common sport fish besides the Atlantic croaker in sport catches". However, bulkheading and other forms of shoreline destruction "may adversely affect the adults" (TPWD, 1975a).

AMERICAN EASTERN OYSTER - *Crassostrea virginica*

The American eastern oyster is found in shallow lagoons and estuarine waters attached to a hard or semihard substrate. Reefs, which are oyster colonies usually living on a substrate of discarded oyster shells, are generally found perpendicular to the prevailing currents in an area (Fotheringham and Brunenmeister, 1973). Each oyster on the reef is thus exposed to a flow of water carrying fresh supplies of food and oxygen. Oysters are still found in every bay along the Texas coast although their numbers have declined somewhat in recent years due to alteration of their habitat by man (TPWD, 1975b; TPWD, 1975c; TPWD, 1975d). Oysters do not migrate as adults, but their larvae are carried about by currents until they settle. When larvae reach the settling stage, they are known as "spat", and may control their movements to some extent by closing their valves and sinking to the bottom (TPWD, 1975f). Larvae must settle onto a hard substrate to survive to maturity (TPWD, 1975b). Spawning of adults is induced whenever the water temperature rises to 75°F, therefore, on the Texas coast, spawning occurs between April and October (TPWD, 1975f).

SQUID - *Lolliguncula brevis*

This small squid species prefers relatively high salinities but will still enter the bays (Gunter, 1950). They enter the bays as the temperatures rise in late winter, remaining near the Gulf passes and returning to the Gulf in the fall (Gunter, 1950). Although little information is available concerning the time and site of spawning for this species along the Texas coast, it is known that "large numbers of *Loligo*", a closely related genus, "come together to copulate and spawn at the same time and a community pile of egg strings may be formed on the bottom" (Barnes, 1974).

BROWN SHRIMP - *Penaeus aztecus*

The importance of the brown shrimp to the Texas shrimp fishery is well documented, thus indicating the need for a thorough understanding of its life cycle. Spawning takes place throughout the year with a peak in the fall and perhaps an additional peak in the spring (Farfante, 1969). There is some evidence that the larvae "overwinter in nearshore waters and enter estuaries the following spring, probably surviving by burrowing" (Cook and Lindner, 1970). Once within the estuaries, the juveniles, bottom dwellers, seek out the marginal areas of estuarine waters before returning to the deeper waters of the estuaries in two to four weeks (Cook and Lindner, 1970). As adults, the brown shrimp leave the estuaries gradually, usually at night (Farfante, 1969). Some movement southward, parallel to the coast, may occur during the autumn and winter (Gunter, 1962). The adults usually prefer offshore substrates of mud or silt, sometimes of mud, sand or shell (Farfante, 1969). They generally inhabit waters of less than one meter to a depth of ninety-one meters (Gosner, 1971). Abundance varies from year to year (Cook and Lindner, 1970) and may be affected by a number of phenomena both natural and man-made. Floods and late cold spells as well as any adverse conditions within the estuaries during periods when the young are most abundant could prove detrimental to subsequent offshore catches (Cook and Lindner, 1970).

WHITE SHRIMP - *Penaeus setiferus*

Adult white shrimp are found offshore in shallower waters than the brown shrimp, usually at a depth of less than twenty-seven meters (TPWD, 1975b). They prefer substrates of soft mud or silt bottoms or "bottoms of clay or sand with fragments of shell" (TPWD, 1975b). Spawning also takes place in shallower waters than for *Penaeus aztecus* (Fotheringham and Brunenmeister, 1973) and "appears to increase to a single peak and then decline" although the young often seem to have been produced from two or three broods (Lindner and Cook, 1970). The young enter the estuaries in the summer and fall and, as bottom dwellers, utilize many of the same marshes as nurseries previously inhabited by juvenile brown shrimp (TPWD, 1975c). Because of their preference for low salinities, <10 ppt (Cook and Lindner, 1970), these juvenile shrimp seek out the back bays and bayous instead of the marsh areas of the primary bays (TPWD, 1975c). Migrations from the estuaries to the open Gulf are "associated with increasing maturity, intensified by falling temperatures in the latter part of the year" (Lindner and Cook, 1970). Offshore movements generally exhibit a northward trend in late winter and early spring and a southward trend during the fall and early winter (TPWD, 1975f).

PINK SHRIMP - *Penaeus duorarum*

Habitat preferences for the pink shrimp have been described as "estuaries and inner oceanic littoral, predominantly on sand, shell-sand or coral-mud bottom from water's edge to twenty-eight fathoms", rarely deeper (TPWD, 1975f). Spawning seems to be a year-round phenomenon although it increases during the spring, summer and fall and seems to be induced by rising temperatures (Farfante, 1969). The young move to inshore waters and usually arrive at the estuarine nursery grounds as post-larvae (Farfante, 1969). The commercial value of the pink shrimp is less than that of the brown or white shrimp simply because it is less abundant along the Texas coast.(TPWD, 1975f).

BLUE CRAB - *Callinectes sapidus*

The blue crab is found over a variety of bottom types although it seems to prefer a substrate of mud and sand (TPWD 1975a; TPWD 1975f). It is most common inshore due to its preference for brackish waters (McEachron, 1977) but can be found as deep as eighteen fathoms (Hildebrand, 1954). The young have a tendency to inhabit lower salinity waters than the adults (Gunter, 1950) and, in fact, blue crab populations are deleteriously affected when freshwater inflow into a particular estuary is decreased (TPWD, 1975a). Spawning generally takes place in the deeper waters of the Gulf (TPWD, 1975f). Eggs are carried by the females until hatching takes place. This occurs "in the Gulf, or occasionally in the bays" (TPWD, 1975f). The blue crab is not only important as the basis for sport crabbing, but also accounts for the "fourth most commercially important fishery along the Texas coast" (TPWD, 1975f).

Alopias vulpinus - thresher shark
Aprionodon isodon - finetooth shark
Carcharhinus acronotus - blacknose shark
Carcharhinus falciformis - silky shark
Carcharhinus leucas - bull shark
Carcharhinus limbatus - blacktip shark
Carcharhinus longimanus - oceanic whitetip shark
Carcharhinus maculipinnis - spinner shark
Carcharhinus obscurus - dusky shark
Carcharhinus porosus - smalltail shark
Galeocerdo cuvieri - tiger shark
Mustelus canis - smooth dogfish
Negaprion brevirostris - lemon shark
Rhizoprionodon terraenovae - Atlantic sharpnose shark
Carcharodon carcharias - white shark
Isurus oxyrinchus - shortfin mako
Odontaspis taurus - sand tiger
Ginglymostoma cirratum - nurse shark
Rhincodon typus - whale shark
Scyliorhinus retifer - chain dogfish
Sphyrna lewini - scalloped hammerhead
Sphyrna mokarran - great hammerhead
Sphyrna tiburo - bonnethead
Sphyrna tudes - smalleye hammerhead
Etmopterus schultzi
Etmopterus virens
Squalus cubensis - Cuban dogfish
Squatina dumerili - Atlantic angel shark
Dasyatis americana - southern stingray
Dasyatis centroura - roughtail stingray
Dasyatis sabina - Atlantic stingray
Dasyatis sayi - bluntnose stingray
Gymnura micrura - smooth butterfly ray
Manta birostris - Atlantic manta
Aetobatus narinari - spotted eagle ray
Myliobatis freminvillei - bullnose ray
Rhinoptera bonasus - cownose ray
Pristis pectinata - smalltooth sawfish
Pristis perotteti - largetooth sawfish
Breviraja sinusmexicana - short-nosed skate
Raja eglanteria - clearnose skate
Raja lentiginosa - freckled skate
Raja olseni - spreadfin skate
Raja texana - roundel skate
Springeria folirostris
Rhinobatos lentiginosus - Atlantic guitarfish
Narcine brasiliensis - lesser electric ray
Hydrolagus alberti - Gulf ratfish
Lepisosteus oculatus - spotted gar
Lepisosteus osseus - longnose gar
Lepisosteus spatula - alligator gar
Lepisosteus spp.
Albula vulpes - bonefish
Elops saurus - ladyfish
Megalops atlantica - tarpon
Anguilla rostrata - American eel
Ariosoma sp.
Conger oceanicus - conger eel
Congrina dubius
Congrina flava - yellow conger
Congrina gracilior - whiptail conger
Neoconger mucronatus - slender pike eel
Paraconger caudilimbatus - margintail conger
Promyllantor schmitti
Uroconger syringus
Dysomma aphododera - shortbelly eel
Moringua edwardsi - spaghetti eel
Hoplunnis macrurus - silver conger
Hoplunnis tenuis - slender pike conger
Enchelycore sp. - chestnut moray
Gymnothorax ocellatus - ocellated moray
Gymnothorax vicinus - purplemouth moray
Bascanichthys scuticaris - whip eel
Echiophis intertinctus - spotted spoon-nose eel
Echiophis mordax - snapper eel
Echiophis punctifer - stippled spoon-nose eel
Letharchus velifer - sailfin eel
Myrophis punctatus - speckled worm eel
Ophichthus gomesi - shrimp eel
Ophichthus ocellatus - palespotted eel
Alosa chrysochloris - skipjack herring
Brevoortia gunteri - finescale menhaden
Brevoortia patronus - gulf menhaden
Brevoortia tyrannus - Atlantic menhaden
Brevoortia spp.
Dorosoma cepedianum - gizzard shad
Dorosoma petenense - threadfin shad
Etrumeus teres - round herring
Harengula pensacolae - scaled sardine
Opisthonema oglinum - Atlantic thread herring
Sardinella anchovia - Spanish sardine
Sardinella sp.
Anchoa hepsetus - striped anchovy
Anchoa mitchilli - bay anchovy
Anchoa nasuta - longnose anchovy
Anchoa sp.
Anchoviella sp.
Engraulis eurystole - silver anchovy
Hiodon alosoides - goldeye
Leptoderma macrops
Argentina silus - Atlantic argentine
Argentina striata
Astronesthes gemmifer
Chauliodus sloani - viperfish
Esox americanus - redfin pickerel
Esox lucius - northern pike
Gonostoma elongata
Yarrella blackfordi
Photostomias guernei
Echiostoma margarita
Argyropelecus aculeatus
Argyropelecus affinis
Argyropelecus gigas
Argyropelecus hemigymnus
Argyropelecus lynchus lynchus
Argyropelecus olfersi
Polyipnus asteroides
Sternoptyx diaphana
Chlorophthalmus agassizi - shortnose greeneye
Chlorophthalmus chalybeius
Parasudis truculenta - longnose greeneye
Diaphus dumerili
Diaphus intermedius
Lampanyctus supralateralis
Myctophum affine
Saurida brasiliensis - largescale lizardfish
Saurida sp.
Synodus foetens - inshore lizardfish
Synodus poeyi - offshore lizardfish
Synodus synodus - red lizardfish
Synodus sp.
Trachinocephalus myops - snakefish
Ictiobus bubalus - smallmouth buffalo
Arius felis - sea catfish
Bagre marinus - gafftopsail catfish
Ictalurus furcatus - blue catfish
Ictalurus melas - black bullhead
Ictalurus natalis - yellow bullhead
Opsanus beta - gulf toadfish
Opsanus pardus - leopard toadfish
Opsanus spp.
Porichthys porosissimus - Atlantic midshipman
Gobiesox punctulatus - stippled clingfish
Gobiesox strumosus - skilletfish
Antennarius ocellatus - ocellated frogfish
Antennarius radiosus - singlespot frogfish
Antennarius scaber - splitlure frogfish
Antennarius sp.
Histrio histrio - sargassumfish
Lophiomus sp.
Dibranchus atlanticus
Halieutichthys aculeatus - pancake batfish
Ogcocephalus nasutus - shortnose batfish
Ogcocephalus parvus - roughback batfish
Ogcocephalus radiatus - polka-dot batfish
Ogcocephalus spp.
Zalieutes mcgintyi - tricorn batfish
Bregmaceros atlanticus - antenna codlet
Gadella maraldi
Merluccius magnoculus - silver hake
Physiculus fulvus
Steindachneria argentea - luminous hake
Urophycis cirratus - gulf hake
Urophycis floridanus - southern hake
Urophycis sp.
Bathygadus macrops
Bathygadus taillanti
Cariburus zaniophorus
Coelorhynchus caribbaeus
Coelorhynchus carminatus
Hymenocephalus cavernosus
Malacocephalus occidentalis
Nezumia bairdi - marlin-spike
Nezumia hildebrandi
Brotula barbata - bearded brotula
Dicrolene intronigra
Gunterichthys longipenis - gold brotula
Lepophidium graellsi - blackedge cusk-eel

Lepophidium sp.
Neobythites gillii
Neobythites marginatus
Ogilbia sp.
Ophidion grayi - blotched cusk-eel
Ophidion holbrooki - bank cusk-eel
Ophidion welshi - crested cusk-eel
Ophidion spp.
Rissola marginata - striped cusk-eel
Membras martinica - rough silverside
Membras sp.
Menidia beryllina - tidewater silverside
Ablennes hians - flat needlefish
Platybelone argalus - keeltail needlefish
Strongylura marina - Atlantic needlefish
Strongylura notata - redfin needlefish
Strongylura sp.
Tylosurus crocodilus - houndfish
Adinia xenica - diamond killifish
Cyprinodon variegatus - sheepshead minnow
Fundulus grandis - gulf killifish
Fundulus pulvereus - bayou killifish
Fundulus similis - longnose killifish
Lucania parva - rainwater killifish
Cypselurus cyanopterus - margined flyingfish
Cypselurus exsiliens - bandwing flyingfish
Cypselurus melanurus - flyingfish
Cypselurus sp.
Euleptorhamphus velox - flying halfbeak
Hirundichthys rondeleti - blackwing flyingfish
Hyporhamphus unifasciatus - halfbeak
Parexocoetus brachypterus - sailfin flyingfish
Gambusia affinis - mosquitofish
Poecilia latipinna - sailfin molly
Barbourisa rufa
Holocentrus ascensionis - squirrelfish
Holocentrus poco - saddle squirrelfish
Holocentrus rufus - longspine squirrelfish
Holocentrus vexillarius - dusky squirrelfish
Polymixia lowei - beardfish
Hoplostethus mediterraneus
Antigonia capros - deepbody boarfish
Cyttopsis roseus
Zenion hololepis
Zenopsis ocellata - American john dory
Aulostomus maculatus - trumpetfish
Macrorhamphosus gracilis - slender snipefish
Macrorhamphosus scolopax - longspine snipefish
Fistularia tabacaria - bluespotted cornetfish
Hippocampus erectus - lined seahorse
Hippocampus obtuses
Hippocampus zosterae - dwarf seahorse
Hippocampus sp.
Syngnathus elucens - shortfin pipefish
Syngnathus floridae - dusky pipefish
Syngnathus fuscus - northern pipefish
Syngnathus louisianae - chain pipefish
Syngnathus pelagicus - sargassum pipefish
Syngnathus scovelli - gulf pipefish
Sygnathus sp.
Acanthurus bahianus - ocean surgeon
Acanthurus chirurgus - doctorfish
Acanthurus coeruleus - blue tang
Apogon aurolineatus - bridle cardinalfish
Apogon maculatus - flamefish
Apogon pseudomaculatus - twospot cardinalfish
Apogon townsendi - belted cardinalfish
Epigonus pandionis
Synagrops bella - blackmouth cardinalfish
Synagrops spinosa
Blennius cristatus - molly miller
Blennius marmoreus - seaweed blenny
Chasmodes bosquianus - striped blenny
Hypleurochilus geminatus - crested blenny
Hypsoblennius ionthas - freckled blenny
Ophioblennius atlanticus - redlip blenny
Caulolatilis cyanops - blackline tilefish
Caulolatilis intermedius - Gulf bar-eyed tilefish
Caulolatilus microps - gray tilefish
Lopholatilus chamaeleonticeps - tilefish
Malacanthus plumieri - sand tilefish
Alectis crinitus - African pompano
Caranx bartholomaei - yellow jack
Caranx hippos - crevalle jack
Caranx latus - horse-eye jack
Caranx ruber - bar jack
Chloroscombrus chrysurus - Atlantic bumper
Elagatis bipinnulata - rainbow runner
Hemicaranx amblyrhynchus - bluntnose jack
Naucrates ductor - pilot fish
Oligoplites saurus - leatherjacket
Selar crumenophthalmus - bigeye scad
Selene vomer - lookdown
Seriola dumerili - greater amberjack
Seriola rivoliana - almaco jack
Seriola zonata - banded rudderfish
Trachinotus carolinus - Florida pompano
Trachinotus crocodilus
Trachinotus falcatus - permit
Trachinotus goodei - palometa
Trachinotus sp.
Trachurus lathami - rough scad
Uraspis secunda - cottonmouth jack
Vomer setapinnis - Atlantic moonfish
Gyrinomimus simplex
Lepomis gulosus - warmouth
Micropterus salmoides - largemouth bass
Pomoxis annularis - white crappie
Pomoxis nigromaculatus - black crappie
Centropomus undecimalis - snook
Centropyge argi - cherubfish
Chaetodon aculeatus - longsnout butterflyfish
Chaetodon aya - bank butterflyfish
Chaetodon capistratus - foureye butterflyfish
Chaetodon ocellatus - spotfin butterflyfish
Chaetodon sendentarius - reef butterflyfish
Chaetodon striatus - banded butterflyfish
Holacanthus bermudensis - blue angelfish
Holacanthus ciliaris - queen angelfish
Holacanthus tricolor - rock beauty
Pomacanthus arcuatus - gray angelfish
Pomacanthus paru - French angelfish
Amblycirrhitus pinos - redspotted hawkfish
Emblemaria pandionis - sailfin blenny
Labrisomus nuchipinnis - hairy blenny
Starksia ocellata - checkered blenny
Coryphaena equisetis - pompano dolphin
Coryphaena hippurus - dolphin
Coryphaena sp.
Echeneis naucrates - sharksucker
Remora australis - whalesucker
Remora osteochir - marlinsucker
Remora remora - remora
Dormitator maculatus - fat sleeper
Eleotris pisonis - spinycheek sleeper
Erotelis smaragdus - emerald sleeper
Gobiomorus dormitor - bigmouth sleeper
Chaetodipterus faber - Atlantic spadefish
Diapterus olisthostomus - Irish pompano
Eucinostomus argenteus - spotfin mojarra
Eucinostomus gula - silver jenny
Eucinostomus spp.
Gerres cinereus - yellowfin mojarra
Ulaema lefroyi - mottled mojarra
Bathygobius soporator - frillfin goby
Bollmannia communis - ragged goby
Coryphopterus punctipectophorus - spotted goby
Evorthodus lyricus - lyre goby
Gnatholepis thompsoni - goldspot goby
Gobioides broussonneti - violet goby
Gobionellus boleosoma - darter goby
Gobionellus hastatus - sharptail goby
Gobionellus oceanicus - highfin goby
Gobionellus shufeldti - freshwater goby
Gobionellus smaragdus - emerald goby
Gobionellus sp.
Gobiosoma bosci - naked goby
Gobiosoma ginsburgi - seaboard goby
Gobiosoma longipala - twoscale goby
Gobiosoma oceanops - neon goby
Gobiosoma robustum - code goby
Gobiosoma sp.
Ioglossus calliurus - blue goby
Lythrypnus nesiotes - island goby
Lythrypnus spilus - bluegold goby
Microgobius gulosus - clown goby
Microgobius thalassinus - green goby
Quisquilius hipoliti - rusty goby
Risor ruber - tusked goby
Rypticus maculatus - whitespotted soapfish
Rypticus saponaceus - greater soapfish
Rypticus subbifrenatus - spotted soapfish
Istiophorus platypterus - sailfish
Makaira nigricans - blue marlin
Tetrapturus albidus - white marlin
Tetrapturus pfluegeri - longbill spearfish
Kyphosus incisor - yellow chub
Kyphosus sectatrix - Bermuda chub

Kyphosus sp. - chub
Bodianus pulchellus - spotfin hogfish
Bodianus rufus - Spanish hogfish
Clepticus parrai - creole wrasse
Halichoeres bivittatus - slippery dick
Halichoeres garnoti
Halichoeres radiatus - pudding wife
Hemipteronotus novacula - pearly razorfish
Lachnolaimus maximus - hogfish
Thalassoma bifasciatum - bluehead
Lobotes surinamensis - tripletail
Lutjanus analis - mutton snapper
Lutjanus apodus - schoolmaster
Lutjanus campechanus - red snapper
Lutjanus cyanopterus - cubera snapper
Lutjanus griseus - gray snapper
Lutjanus synagris - lane snapper
Ocyurus chrysurus - yellowtail snapper
Pristipomoides aquilonaris - wenchman
Rhomboplites aurorubens - vermilion snapper
Microdesmus longipinnis - pink wormfish
Microdesmus sp.
Agonostomus monticola - mountain mullet
Mugil cephalus - striped mullet
Mugil curema - white mullet
Mugil sp.
Mulloidichthys martinicus - yellow goatfish
Pseudupeneus maculatus - spotted goatfish
Upeneus parvus - dwarf goatfish
Lonchopisthus lindneri - swordtail jawfish
Bembrops anatirostris - duckbill flathead
Bembrops gobioides - goby flathead
Polydactylus octonemus - Atlantic threadfin
Abudefduf saxatilis - sergeant major
Abudefduf taurus - night sergeant
Chromis cyanea - blue chromis
Chromis enchrysura - yellowtail reeffish
Chromis insolatus - sunshinefish
Chromis multilineatus - brown chromis
Chromis scotti - purple reeffish
Microspathodon chrysurus - yellowtail damselfish
Pomacentrus dorsopunicans - dusky damselfish
Pomacentrus fuscus - dusky damselfish
Pomacentrus leucostictus - beaugregory
Pomacentrus partitus - bicolor damselfish
Pomacentrus planifrons - yellow damselfish
Pomacentrus variabilis - cocoa damselfish
Anisotremus surinamensis - black margate
Anisotremus virginicus - porkfish
Conodon nobilis - barred grunt
Haemulon aurolineatum - tomtate
Haemulon macrostomum - Spanish grunt
Haemulon melanurum - cottonwick
Haemulon parrai - sailors choice
Haemulon striatum - striped grunt
Orthopristis chrysoptera - pigfish
Pomadasys crocro - burro grunt
Pomatomus saltatrix - bluefish
Priacanthus arenatus - bigeye
Priacanthus cruentatus - glasseye snapper
Pseudopriacanthus altus - short bigeye
Rachycentron canadum - cobia
Scarus taeniopterus - princess parrotfish
Scarus vetula - queen parrotfish
Sparisoma aurofrenatum - redband parrotfish
Sparisoma radians - bucktooth parrotfish
Sparisoma viride - stoplight parrotfish
Bairdiella chrysura - silver perch
Cynoscion arenarius - sand seatrout
Cynoscion nebulosus - spotted seatrout
Cynoscion nothus - silver seatrout
Cynoscion sp.
Equetus lanceolatus - jackknife fish
Equetus umbrosus - cubbyu
Larimus fasciatus - banded drum
Leiostomus xanthurus - spot
Menticirrhus americanus - southern kingfish
Menticirrhus littoralis - gulf kingfish
Menticirrhus saxatalis - northern kingfish
Menticirrhus sp.
Micropogon undulatus - Atlantic croaker
Odontoscion dentex - reef croaker
Pogonias cromis - black drum
Sciaenops ocellata - red drum
Stellifer lanceolatus - star drum
Umbrina coroides - sand drum
Acanthocybium solanderi - wahoo
Auxis thazard - frigate mackerel
Euthynnus alletteratus - little tunny
Euthynnus pelamis - skipjack tuna
Sarda sarda - Atlantic bonito
Scomber japonicus - chub mackerel
Scomberomorus cavalla - king mackerel
Scomberomorus maculatus - Spanish mackerel
Scomberomorus regalis - cero
Thunnus atlanticus - blackfin
Thunnus thynnus - bluefin tuna
Neomerinthe hemingwayi - spinycheek scorpionfish
Pontinus longispinis - longspine scorpionfish
Scorpaena brasiliensis - barbfish
Scorpaena calcarata - smoothhead scorpionfish
Scorpaena dispar - hunchback scorpionfish
Scorpaena plumieri - spotted scorpionfish
Scorpaenodes caribbaeus - reef scorpionfish
Setarches parmatus
Centropristis ocyurus - bank sea bass
Centropristis philadelphica - rock sea bass
Diplectrum bivittatum - dwarf sand perch
Diplectrum formosum - sand perch
Epinephelus adscensionis - rock hind
Epinephelus cruentatus - graysby
Epinephelus drummondhayi - speckled hind
Epinephelus flavolimbatus - yellowedge grouper
Epinephelus guttatus - red hind
Epinephelus inermis - marbled grouper
Epinephelus itajara - jewfish
Epinephelus morio - red grouper
Epinephelus nigritis - Warsaw grouper
Epinephelus niveatus - snowy grouper
Gonioplectrus hispanus - Spanish flag
Hemanthias leptus - longtail bass
Hemanthias vivanus - red barbier
Hypoplectrus chlorurus - yellowtail hamlet
Hypoplectrus unicolor - butter hamlet
Liopropoma eukrines - wrasse bass
Liopropoma rubre - peppermint bass
Morone saxatilis - striped bass
Mycteroperca bonaci - black grouper
Mycteroperca interstitialis - yellowmouth grouper
Mycteroperca microlepis - gag
Mycteroperca phenax - scamp
Mycteroperca rubra - comb grouper
Mycteroperca sp.
Paranthias furcifer - creole-fish
Pikea mexicana - yellowtail bass
Serraniculus pumilio - pygmy sea bass
Serranus atrobranchus - blackear bass
Serranus phoebe - tattler
Serranus subligarius - belted sandfish
Archosargus probatocephalus - sheepshead
Calamus arctifrons - grass porgy
Calamus bajonado - jolthead porgy
Calamus calamus - saucereye porgy
Calamus campechanus - Campeche porgy
Calamus leucosteus - whitebone porgy
Calamus nodosus - knobbed porgy
Calamus penna - sheepshead porgy
Calamus sp.
Diplodus holbrooki - spottail pinfish
Lagodon rhomboides - pinfish
Stenotomus caprinus - longspine porgy
Sphyraena barracuda - great barracuda
Sphyraena borealis - northern sennet
Sphyraena guachancho - guaguanche
Ariomma bondi - silver-rag
Centrolophus niger - black ruff
Hyperoglyphe bythites
Nomeus gronovii - man-of-war fish
Peprilus alepidotus - harvestfish
Peprilus burti - gulf butterfish
Peprilus simillimus - Pacific pompano
Psenes pellucidus - blackrag
Trichiuris lepturus - Atlantic cutlassfish
Bellator militaris - horned searobin
Peristedion longispathum
Peristedion miniatum - armored searobin
Peristedion gracile - slender searobin
Prionotus evolans - striped searobin
Prionotus martis - barred searobin
Prionotus ophryas - bandtail searobin
Prionotus paralatus - Mexican searobin
Prionotus roseus - bluespotted searobin
Prionotus rubio - blackfin searobin
Prionotus salmonicolor - blackwing searobin
Prionotus scitulus - leopard searobin
Prionotus stearnsi - shortwing searobin
Prionotus tribulus - bighead searobin
Prionotus sp.

Astroscopus y-graecum - southern stargazer
Gnathagnus egregius - freckled stargazer
Kathetostoma albigutta - lancer stargazer
Xiphias gladius - swordfish
Ancylopsetta dilecta - three-eye flounder
Ancylopsetta quadrocellata - ocellated flounder
Bothus spp.
Citharichthys cornutus - horned whiff
Citharichthys macrops - spotted whiff
Citharichthys spilopterus - bay whiff
Citharichthys sp.
Cyclopsetta chittendeni - Mexican flounder
Cyclopsetta fimbriata - spotfin flounder
Engyophrys senta - spiny flounder
Etropus crossotus - fringed flounder
Etropus sp.
Monolene sessilicauda - deepwater flounder
Paralichthys albigutta - gulf flounder
Paralichthys lethostigma - southern flounder
Paralichthys squamilentus - broad flounder
Paralichthys sp.
Syacium gunteri - shoal flounder
Syacium papillosum - dusky flounder
Trichopsetta ventralis - sash flounder
Symphurus civitatus - offshore tonguefish
Symphurus diomedianus - spottedfin tonguefish
Symphurus parvus - pygmy tonguefish
Symphurus pelicanus - longtail tonguefish
Symphurus piger - deepwater tonguefish
Symphurus plagiusa - blackcheek tonguefish
Symphurus sp.
Poecilopsetta beani
Achirus lineatus - lined sole
Gymnachirus texae - fringed sole
Trinectes maculatus - hogchoker
Aluterus heudeloti - dotterel filefish
Aluterus schoepfi - orange filefish
Aluterus scriptus - scrawled filefish
Balistes capriscus - gray triggerfish
Balistes vetula - queen triggerfish
Canthidermis sufflamen - ocean triggerfish
Cantherhines pullus - orangespotted filefish
Melichthys niger - black durgon
Monacanthus ciliatus - fringed filefish
Monacanthus hispidus - planehead filefish
Monacanthus setifer - pygmy filefish
Xanthichthys ringens - sargassum triggerfish
Chilomycterus schoepfi - striped burrfish
Diodon holocanthus - balloonfish
Diodon hystrix - porcupinefish
Mola lanceolata - sharptail mola
Mola mola - ocean sunfish
Lactophrys quadricornis - scrawled cowfish
Lactophrys trigonus - trunkfish
Lactophrys triqueter - smooth trunkfish
Lactophrys sp.
Canthigaster rostrata - sharpnose puffer
Lagocephalus laevigatus - smooth puffer
Sphoeroides dorsalis - marbled puffer
Sphoeroides nephelus - southern puffer
Sphoeroides pachygaster - blunthead puffer
Sphoeroides parvus - least puffer
Sphoeroides spengleri - bandtail puffer
Sphoeroides testudineus - checkered puffer
Sphoeroides sp.
Parahollardia lineata - jambeau

TABLE I

COMMERCIAL FISH LANDINGS

Yearly Mean for Six Year Period

(September 1972 - August 1978)

	Gulf Landings		Bay Landings	
Fish	Mean Pounds	Mean Value	Mean Pounds	Mean Value
Pompano	1,712	$ 1,049	3,108	$ 1,487
Red Snapper	606,868	396,652	*1,587	*1,319
Mullet	33,982	2,230	37,589	2,904
White Seatrout	1,974	671	13,967	4,466
Spotted Seatrout	244,792	94,750	1,448,911	597,614
Croaker	31,070	2,401	67,528	5,845
Blackdrum	65,303	9,774	1,431,923	316,855
Redfish	92,916	33,632	1,517,116	597,989
Sheepshead	48,075	5,823	273,008	24,382
Flounder	224,733	70,300	185,219	82,081
American Eastern Oyster	--	--	2,566,731	2,238,621
Squid	7,191	1,663	5,142	1,260
Brown and Pink Shrimp	58,641,732	75,839,846	3,966,214	1,629,653
White Shrimp	*10,307,259	*13,778,960	7,124,062	5,950,077
Blue Crab	47,739	5,987	6,736,685	1,204,318

* yearly mean for less than six year period

EFFECTS OF OIL ON BIOLOGICAL SYSTEMS

Introduction

Oil pollution of the sea from various sources is fast becoming a serious global problem. Oil pollution does not respect any national boundaries--nor are its effects easy to predict. Some marine life seems almost unaffected by oil, but under other conditions oil is lethal to a variety of species.

Research on the effects of oil on living organisms has been performed in the laboratory since the beginning of the century, but most of the early research lacked adequate controls, or description of the oil or oil fractions used. Other conclusions concerning the effects of oil on marine life have been drawn from studies of oil spills in the past. A great deal of enlightenment has been obtained from studies of major spills, such as Santa Barbara and Amoco Cadiz. This paper summarizes briefly the toxic effects of oil on marine organisms, the factors affecting oil toxicity, and the possible effects of the Ixtoc I oil spill.

Evans and Rice (1974) list eight ways in which oil poses a potential danger to marine life:

(1) Direct kill of organisms through coating and asphyxiation.
(2) Direct kill through contact poisoning of organisms.
(3) Direct kill through exposure to the water-soluble toxic components of oil at some distance in space and time from the accident.
(4) Destruction of the generally more sensitive juvenile forms of organisms.
(5) Destruction of the food sources of higher species.
(6) Incorporation of sublethal amounts of oil and oil products into organisms (resulting in reduced resistance to infection

and other stresses--the principal cause of death in birds surviving immediate exposure to oil).

(7) Incorporation of carcinogenic and potentially mutagenic chemicals into marine organisms.

(8) Low-level effects that may interrupt any of numerous events (such as prey location, predator avoidance, mate location or other sexual stimuli, and homing behavior) necessary for the propagation of marine species and for the survival of those species higher in the marine food web.

All of these short-term effects have been documented either in laboratory or field experiments. The long-term effects on marine life of an accumulation of tar from successive spills have not yet made themselves felt.

I. Effects on Marine Organisms

A. Primary Producers

Most of the biomass of the ocean is in the form of one-celled pelagic plants known as phytoplankton. Phytoplankton potentially could be affected severely by oil spills since a large proportion of the phytoplankton is near the surface of the water, where oil concentrates and has its greatest effects. Galtsoff et al. (1935) examined the effect of oil and oil extracts on the diatom *Nitzchia closterium* E. A heavy layer of surface oil left on the surface longer than a week tended to inhibit growth of the diatom. When diatom cultures were treated with oil extracts at a concentration of 25% or higher for a considerable period of time, growth was retarded. Similarly, Sanborn (1977) found an immediate and complete loss of photosynthesis occurred when the flagellate *Chlamydomonas angulosa* was treated with aqueous extracts. Sanborn concluded that the effects of oil on the species can only be surmised. These results are at odds with recently published studies by Pulich (1979) who found no observable effects of weathered Mexican oil on photosynthesis of cultures of diatoms and green flagellates. Pulich (1979) however warns that the experimental results should not be interpreted to mean that Mexican oil will have no effect on growth and cell division of Gulf of Mexico phytoplankton populations. He points out, for example, that some lethal hydrocarbon compounds had no immediate effect on photosynthesis.

Inshore, grasses are major producers of biomass and provide shelter and food to larvae and adults of a wide variety of species. Marsh grass seems to be especially vulnerable to the toxic coating effect of spilled oil (Roland et al., 1977, Nadeau and Bergquist, 1977). However, marshes and estuarine systems have a high energy flow which may reduce the residence time of the oil in the marsh grass system (Hershner and Moore, 1977). Mangroves also can be severely affected, especially young trees (E. I. Chan, 1977).

At this time, the total effect of spilled oil on marine plant life could only be surmised, even if more complete information was available. Oil probably affects some species more severely than others and individual laboratory testing is needed to determine harmful amounts. For mangroves and sea grass communities to recolonize following a fatal spill should take quite a long time in nature due to changes in the substrate in which they grow and the long generation time of these species. Phytoplankton, on the other hand, should recover fairly quickly due to its immense powers of reproduction.

B. Primary Consumers

1. Zooplankton

The most important group of primary consumers in the Gulf of Mexico is the zooplankton population. There are two important kinds of zooplankton. The first are organisms which remain in the zooplankton their entire lives, such as copepods, amphipods and other small crustaceans. There also are zooplankters which are the eggs and larvae of larger organisms such as fish, molluscs and larger crustaceans. Both kinds of zooplankton feed on phytoplankton and smaller zooplankters.

Descriptions of the general effect of oil on zooplankton of the first kind have sometimes been published, with contradictory results. Sanborn (1977) reported no harmful effects of oil on zooplankton after the Santa Barbara or the Torrey Canyon spills. The University of Texas Marine Science Institute (1977) stated that although hydrocarbon fractions were found in zooplankton tissues, indicating substantial petroleum contamination, there was no observable effect. Sanborn also reported that the ingestion of oil had no effect on zooplankton. In contrast, Galtsoff et al. (1935) reported that Elmhirst in 1922 found that plankton was killed by contact with oil. How Elmhirst performed his experiment is not known.

Several species of planktonic invertebrate larvae have been subjected to oil extracts. Sanborn (1977) reported that some planktonic larvae of benthic invertebrates are killed by contact with oil pollution. In particular, the gametes of these invertebrates, which are released into the water, are extremely sensitive. The larvae in an oil polluted area during the period of the spill could experience possible mortality through eutrophication of the water, change in the sediment on which they would settle, direct poisoning, or the disappearance of gregarious settled larvae followed by failure to recolonize (Sanborn, 1977).

Larvae and eggs of fishes have also been exposed to oil. Sanborn (1977) says that pilchard eggs showed high mortality in the Torrey Canyon spill. Also, developing eggs of the Black Sea flatfish, *Rhombus maesticus*, were highly sensitive to oil and oil products down to a concentration of 10^{-5}ml/liter. Hatched larvae were more resistant. On the Texas coast, Arnold et al. (1979) found that redfish (*Sciaenops ocellata*) larvae and eggs both experienced mortality and developmental abnormalities when exposed to water soluble fractions of oil. As with the plant life, the effect of oil on the zooplankton probably varies with the species. The small planktonic organisms which reproduce rapidly would probably not be long affected by oil pollution, no matter how severe the initial kill. The planktonic larvae and eggs, which seem more susceptible to oil pollution on the weight of the data, would also be more severely affected due to their much longer generation time.

2. Benthic Invertebrates

a. Oyster

The American eastern oyster, *Crassostrea virginica*, has been one of the most widely used organisms for oil spill studies. The species is widely used for food, but oil pollution gives oysters an oily taste, making them unmarketable (Galtsoff et al., 1935; St. Amant, 1970), and therefore research on this species has been stimulated. Also, the filter-feeding mechanism of the oyster raises the question of what happens to an organism that strains oil from the water along with its food. Oysters also make good subjects for experiments because of their sedentary habits, which make large tanks unnecessary.

Other effects on oysters of natural oil spills have been categorized as mortality, tarry coating on the shells, watery color and texture, reduced glycogen content, and reduction of gonad development (Galtsoff et al., 1935).

Weathered oil sinks to the bottom and when released by storms, oyster harvesting or dredging, continues to have the same effects (Galtsoff et al., 1935).

Laboratory experiments on oysters show that they are not greatly affected by oil in seawater unless the water is stagnant (Galtsoff et al., 1935). Lund (1957) measured the ability of oysters to clear water of food particles and found that high concentrations of bleedwater, greater than 15%, slowed the ability of the oysters to clear the water. Soluble oil fractions and crude oil at low concentrations had no effect on the oyster's ability to clear the water or take in suspended matter.

Oysters can protect themselves from large doses of oil in water by closing their valves tight and excluding water from their shells. Varanasi and Malins (1977) found that oysters remained closed when there was 900 mg/liter crude oil in the water. Oysters, like many other marine species, can also remove assimilated hydrocarbons from their tissues once the oil has disappeared from the water.

The weight of the data indicates that while oil has potentially severe effects on oysters, an oil spill, with diluted and weathered oil, will not result in serious mortality in the oyster population. A large spill directly on the reef would probably result in serious loss. However, even small spills may lower the oyster's commercial value by affecting its taste, and little is known about the effects of oil on the ability of oyster larvae to settle. While the adult oysters can protect themselves from oil by closing their valves, the spat are more vulnerable to oil, especially oil on the rocks where they are to settle (Sanborn, 1977).

b. Other Molluscs and Annellid Worms

Benthic invertebrates, such as other mollusks beside oysters, and annellid worms are severely affected by settlement of oil on the substrate (Sanborn, 1977). Those organisms which are filter-feeders may have their gills or filter mechanisms clogged by oil or tar particles, smothering the animal. This danger is greatest for those benthic organisms which live in the subtidal or intertidal zones, near the shore, where oil is most likely to be washed up.

In one incident, polychaetes suffered mortalities when cracking residue thinned with Number 2 fuel oil was spilled on the beach (Sanborn, 1977). Benthic worms are especially vulnerable to the smothering effects of oil, even weathered oil. Isopods, small crustaceans which are important scavengers, are trapped and killed by oil spilled in the intertidal region (Cubit, 1970). Other benthic organisms below the high tide mark are likely to suffer the same fate. Other effects on benthic animals may stem from alteration of the substrate rather than asphyxiation or coating. For example, the polychaete bloodworm *Euzonus mucronata* usually burrows to the top of the sand during receding tides. When the sand was coated with spilled oil the worms avoided the surface (Cubit, 1970).

Oil in the sediment affects molluscs, such as clams. For instance, large numbers of Pismo clams, *Tivela stultorum*, and razor clams, *Siligua patula*, were killed by spills of diesel oil in California (Sanborn, 1977). Here only the initial kill was reported, but oil in sediments may result in continuing mortality. A serious spill of No. 2

fuel oil mixed with JP5 jet fuel in Searsport, Maine caused continued mortality of clams of the genus *Mya*, with 85% of the harvestable population killed in 3 years. The estimated loss was 50 million clams. The surviving clams had a high incidence of gonadal tumors which in some cases replaced gonadal tissue. Note that this spill involved refined products which would be expected to be more dangerous to marine life, due to their lower molecular weight (Sanborn, 1977). Further evidence of the tendency of hydrocarbons to remain in the sediment is provided by a spill of crude oil in Casco Bay, Maine, where the clams still showed contamination nine years after the spill (Sanborn, 1977).

3. Fishes

Two common species of fish, the striped mullet, *Mugil cephalus* L. and the Atlantic menhaden, *Brevoortia patronus*, can be considered primary consumers, as they feed mostly on the plankton. Adult fishes are presumably more able to avoid oil spills than other marine species since their mobility is greater. Thus one would expect fish species to make contact with oil mainly in the act of feeding upon oiled food items. Fishes which filter small items out of the water in the act of feeding would seemingly be more likely to ingest oil than those which eat larger items. St. Amant (1970) states that menhaden are not affected by oil pollution, although he notes that fishes that have fed upon oily food develop an oily taste. More information is needed on these species, which are important members of the food web.

C. Secondary Consumers

1. Shrimp

Gulf shrimp of the genus *Penaeus* are an important part of the food chain. They feed on smaller crustaceans and plankton of all sorts, and are a preferred food of all the larger fish species. Man also prefers these shrimp, known as white, brown, and pink shrimp, as an item of his diet.

Shrimp, being partly filter-feeders, are susceptible to ingesting oil or tar particles, or becoming entangled in oil. A recent study by Flint et al. (1979) found slight mortality (9%) at the highest concentration of oil accommodated water, and less mortality at lower concentrations. This shows that besides the clogging effect on gills of oil particles, shrimp are affected by direct toxicity of oil. As with all the organisms that have planktonic larval stages, the possibility that the larvae may be more severely affected than the adults cannot be ignored (Evans and Rice, 1974).

2. Fishes

Sanborn (1977) lists 5 possible ways in which an oil spill can cause damage to fish populations: First, egg and larval mortality by direct coating or toxic effects, (2) Adults could be killed in a similar way in narrow or shallow water, (3) Contamination of spawning grounds, (4) Fecundity or spawning behavior may change, and (5) Local food species may be adversely affected.

In a study of fishes of "oiled" and "nonoiled" environments, Ebeling et al. (1970) found no significant difference between them. St. Amant in 1970 reported that commercial fishes faced with chronic oil pollution have not experienced any serious breakdown in the food chain or animal life cycles. Nevertheless, he recognized that finfishes which feed on lower forms which have ingested oil develop an unpleasant oily taste which could affect their market value (St. Amant, 1970). More serious than the oily taste from ingestion of oil in food, is the fact that fishes also assimilate oil hydrocarbons directly from the water. One experiment, cited in Galtsoff et al. (1935), found that an extract prepared by shaking 100cc of oil with 2,000cc of distilled water was toxic to brown trout.

Young and larval fishes are generally more adversely affected by oil pollution (Craddock, 1971). This has been observed in larvae of plaice and flounders (Galtsoff et al., 1935), and pilchard eggs and eggs of Black Sea flatfishes (Sanborn, 1977). Arnold et al. (1979) found a very definite statistical relationship: as the concentration of oil in water rose, the number of fish eggs and larvae which were deformed or dead also rose. Although from the foregoing experiments it appears that small larvae are sensitive to oil, one set of experiments seems to indicate the reverse. Gardinier (1927), cited in Galtsoff et al. (1935), reported that trout when only 60 days old showed no effects from 2-hour immersion in a 40 phenol:100,000 water solution. The same species, when 110 days old, was unable to withstand a 15-minute immersion. Most early experiments on oil toxicity are suspect because at that time the experimental methodology was not as rigorous as it has become, and the results were often not reported in statistically analyzable form. Modern experiments, such as Arnold et al. (1979), are much more trustworthy.

Studies indicate that the commercial fishery in the Black Sea has been nearly ruined by oil pollution. Sanborn (1977) states that the first sign was a fall in zooplankton productivity. Since 1930, sturgeon catches have dropped to one-third of their former level, and salmon, bream, carp, and sild catch have dropped to one-tenth. The Black Sea is nearly landlocked, Sanborn points out, and oil can't escape or be diluted as in other bodies of water. The chronic oil pollution problem there is very bad. The North and Baltic Seas have also been frequently polluted by spilled oil for decades, but Sanborn reports no effect on the fish population. He attributes this to the better exchange of water between the Baltic Sea, the North Sea and the Atlantic Ocean.

3. Squid

Squid are generalized predators, occupying roughly the same place in the food chain as sport fishes such as the redfish. Squid lay their eggs on the bottom, so one might postulate that their immature stages would not be as susceptible to direct toxic effects as the floating eggs of fishes. No experiments on effects of oil on squid were located in the literature search.

4. Crabs

Crabs are considered secondary consumers because of their appetite for flesh, but much of their food is obtained from scavenging. The blue crab, *Callinectes sapidus*, is abundant over much of the world, and especially common in the Gulf of Mexico. It is the object of a considerable sport and commercial fishery, as crab meat is considered a delicacy.

All the crabs have planktonic larvae, which are vulnerable to floating oil, like other zooplankton. Adult crabs are likely to become exposed to weathered oil or tar when scavenging on or near the bottom. More needs to be known about the effect of oil on the life stages of the blue crab.

5. Birds

A number of migratory and native bird species depend mostly or wholly upon the productivity of the Gulf, bay and estuarine areas of the Texas coast. Birds in general are very vulnerable to spilled oil, which coats their feathers and renders them useless for flying or insulation against cold. Birds attempting to preen oil out of their feathers may then succumb to the toxic effects of petroleum. Oiled seabirds are one of the first obvious effects of an oil spill (Gorman and Simms, 1978). More than 3,450 birds of 33 species were killed by the Amoco Cadiz spill in 1978 and other oil spills have almost invariably taken a large toll (Jones et al., 1978). Mortality continues up to 300 days after the birds' exposure to oil (Cowell, 1976).

Sublethal effects on birds from exposure to spilled oil include enteric respiratory disorders, renal disorders, lung infections, arthritis, and dessication through physiological imbalances and metabolic changes (Cowell, 1976). A good idea of the danger that spilled oil presents to birds can be had from the fact that only 5% of auks, when cleaned and kept in captivity, recover from oil coatings. Gulls and ducks, which adjust better to cleaning, may have a recovery rate of 75% (Cowell, 1976). Gorman and Simms (1978) found that ingested crude oil did not result in slower growth in nestling gulls, as had been earlier reported. This may indicate that ingestion of oil is relatively unimportant, and that most of the bird mortality occurs from oil coating bird plumage.

Although seabirds are appreciated more for their aesthetic value than for any commercial value they might have, their susceptibility to oil should be investigated further, since they are warm-blooded animals like man, and are relatively high in the food chain.

D. Tertiary Consumers

1. Man

Man should be less vulnerable to toxic effects of oil that he ingests in his food, because man is the only animal who exercises rigid quality control over his food. This is in contrast to the behavior of plaice, *Pleuronectes platessa*, which prefer to eat oiled shrimp, since they are caught more easily than healthy ones (Sanborn, 1977).

Oil spills are likely to affect man by removing items from his diet. Not only will contaminated food be unfit for human consumption, but toxic effects may kill off food species thus reducing the efficiency of the fish and shrimp harvesting industry. Low levels of hydrocarbon pollution can result in carcinogenic or mutagenic chemicals in the human diet.

II. Factors Affecting the Toxicity of Oil

A. Chemical Factors

Most damage to wildife is done by the most volatile fractions of oil. There is general agreement that the smaller the hydrocarbon molecule, the greater its toxicity to life. (Cowell, 1976, Moore and Dwyer, 1974). Aromatic hydrocarbons (those molecules containing an aromatic or benzene ring) are more toxic than straight chain or branched ones (Evans and Rice, 1974). Toxicity of molecules increases in the series paraffins, naphthalenes, olefins and aromatics, according to Cowell (1976). Molecules which are more soluble in water pose a greater risk of being assimilated (Cowell, 1976). Most authors therefore state with good reason that the low boiling, more water-soluble aromatics are the primary cause of immediate biological damage.

B. Physical Factors

When exposed to atmospheric conditions, oil tends to break down, a process known as weathering. On a volume basis, oil becomes less toxic to life the longer it weathers (Bender, 1977). Evaporation of the smaller, more volatile molecules is the major weathering process which removes the most toxic molecules from the marine environment. Other hydrocarbons undergo photooxidation, a process in which they are broken down into smaller molecules by solar radiation in the presence of oxygen. Although this process is not as fast as evaporation, it continues to break down the large molecules after the smaller ones have been lost through evaporation.

Burning of the spilled oil, of course, greatly accelerates its removal from the oceanic environment. The constituents most likely to be oxidized by burning are the small molecules and aromatics. This process generates heat which evaporates other oil molecules. Although burning renders the more dangerous components of spilled oil harmless to marine life, the air pollution effects from hydrocarbon smoke on all terrestrial life can be serious.

Oil can be removed from the water by adsorption onto suspended sediments which then settle to the bottom. This was a major factor in carrying much of the spilled oil to the sea floor following the Santa Barbara spill in 1969 (Evans and Rice, 1974).

Physical effects can increase the toxicity of oil as well as decrease it. Mixing of oil with water can cause the more water-soluble components to go into solution more quickly, and cause increased mortality. In one example, intense onshore winds and shallow water caused oil droplets to mix with water which caused sudden mortality in sea cucumbers, conchs, prawns, sea urchins and polychaetes (Nadeau and Bergquist, 1977).

Oil may act synergistically with physical effects with unexpected consequences. An intertidal barnacle, *Pollicipes polymerus*, is prevented from breeding by the presence of oil in the surrounding area. The cessation of reproduction was linked to a rise in body temperature when the black oil absorbed solar heat (Straughan, 1977).

C. Biological Factors

1. Biodegradation

Two ways in which oil can be detoxified (photooxidation and evaporation) have already been mentioned. The third way in which oil becomes less dangerous to organisms is biodegradation. This process involves the entrance of oil hydrocarbons into the tissues of an animal or plant, and the subsequent oxidation of the molecule as part of the organism's metabolism (Gibson, 1977). The most efficient hydrocarbon oxidizers are certain microorganisms including bacteria, filamentous fungi and yeasts (ZoBell, 1973, Yall, 1979).

Each species of microorganism typically only oxidizes a small spectrum of hydrocarbon compounds, because all of them do not possess the necessary enzymes to break down a wider range of compounds. They are very abundant, however. In oil-polluted harbors or oil dumps there may be 10^3 to 10^6 oil-oxidizing microorganisms per milliliter. In bottom sediments the population may reach 10^9 oil-oxidizing microorganisms per milliliter (ZoBell, 1973).

All of the oil-oxidizing organisms in the bottom sediments are near the surface of the sediment because the oil-oxidizing process is aerobic, requiring dissolved oxygen. Oil deposited in deeper sediments therefore is not biodegraded unless it is exposed to dissolved oxygen by wave action or some other disturbance. There is therefore a danger that successive oil spills will build up layers of tar in marine sediments which will be a barrier to burrowing animals (Cubit, 1970). Alternatively, the oil could be ingested and returned to the biosphere by sediment-inhabiting organisms. The oil-laden sediment could therefore become a source of a chronic oil pollution problem in the area where the spill occurred (Evans and Rice, 1974).

Hydrocarbons are known to remain stable in marine sediments for geologically long periods of time. Crude oil is in fact formed from hydrocarbon sediments which are the remains of marine animals and plants. The effect of such sediments on the living organisms in an area declines with the sediment depth, and therefore its age.

2. Incorporation in the Food Web

Hydrocarbons, when spilled in the marine environment, invariably will enter the food chain. Most hydrocarbons are lipid (fat) soluble and therefore tend to accumulate in fatty tissues of animals that ingest them. As animals that are low in the food chain are eaten by ones that are higher, the hydrocarbons spread throughout the fauna in the area of the oil spill.

Oil is most likely to be incorporated into the food chain when it is freshly spilled. At this time, floating oil is absorbed by zooplankton and phytoplankton. The most toxic molecules have not yet evaporated and are still present in the oil-water mixture at this time. Cox et al. (1975) found that the highest concentration of naphthalenes in seawater was approximately 48 hours after the spill. This was the time of greatest mortality and the highest concentration of naphthalenes in animals sampled from the area. Other hydrocarbons were presumably also present in high concentration.

By 14 days after the spill the naphthalenes reached a peak concentration in the sediment (Cox et al., 1975). This is the time when benthic animals, especially detritus feeders such as annelids, are in the greatest danger of feeling the toxic effects of hydrocarbons. As the concentration of oil drops in succeeding weeks, the toxic effects decrease, but the oil may still enter the food chain through the benthic animals; and will continue to do so until it is buried too deep to be ingested.

Like petroleum hydrocarbons, the chlorinated hydrocarbons such as DDT are fat-soluble and accumulate in the fatty tissues of animals (Evans and Rice, 1974). Chlorinated hydrocarbons also are concentrated in the food chain because animals are not able to excrete them and therefore retain nearly all that they have ingested in their life. This results in mortality and sublethal effects, especially at the top of the food chain, where the effects of DDT on the eggshells of predatory birds are well known. It is now known that DDT is more soluble in petroleum hydrocarbons than in water. Consequently DDT concentrates near the surface of the water when oil is present there, exposing surface organisms to a higher concentration of DDT (Ehrlich et al., 1973).

Opinion is divided on whether oil-derived hydrocarbons accumulate in the food chain. Scarratt and Zitko (1972) note that carnivores tend to have lower concentrations of oil than herbivores and conclude that oil most likely is not concentrated in the food chain. Evans and Rice (1974) cite several authorities in support of the theory that certain hydrocarbons may accumulate in the food chain. They also indicate that oil may be excreted in the feces of animals which have ingested it. There are also many references that document the accumulation of hydrocarbons by marine animals living in oil-polluted water, followed by the return of the hydrocarbons to the environment when the water becomes clean (Anderson and Neff, 1974; Fossato and Conzonier, 1976). Some species studied have also shown an ability to partly metabolize assimilated oil hydrocarbons (Scarratt and Zitko, 1972).

Apparently, the biological fate of hydrocarbon molecules depends on the molecule and the organism involved. An animal or plant in an oil-polluted environment has no choice but to absorb oil from the environment or from its food. If the oil is not passed out immediately in the feces, then it seems there are three things which can happen to an assimilated oil molecule.

(1) The molecule is stored in tissue and accumulates; the animal has no enzyme or transport system to get rid of it.
(2) The molecule is metabolized; the animal possesses the enzymes necessary to break it down.
(3) The molecule is transported out of the body; the animal gets rid of the molecule with the waste products of cellular respiration or cellular breakdown.

Some animals may be porous to certain molecules, taking them up and then releasing them. Processes (2) and (3) happen at some rate which may be too slow to guarantee that all the hydrocarbons are actually excreted or metabolized. In that case the molecules are passed up the food chain in the same way as those molecules which are stored in tissue.

A toxic molecule which occurs in the spilled oil at a low concentration may rise in concentration as it goes up the food chain. This process would be the major danger from hydrocarbon molecules which are not metabolized or transported out of the organism. It could cause mortality to predators at the highest trophic level. Eggs or larvae mortality of the predator species could also be threatened, since embryos usually have a lower tolerance to toxic substances (Craddock, 1971).

It should be remembered that some molecules may also have carcinogenic or disabling effects on the organism even if they are only present within its body for a short time. For an exhaustive listing of sublethal effects on various phyla, see Johnson (1974). Such sublethal effects can be caused by persistent concentrations of soluble aromatic derivatives in the range 10-100 parts per billion (Moore and Dwyer, 1974).

III. Toxicity of Ixtoc I Oil

The best available report on the composition of Ixtoc I oil (Parker et al., 1979) indicates that it is not especially different from other crudes. At the well, Ixtoc I crude contained 52-53% saturated hydrocarbons, 34-35% aromatics and 7-8% NSO compounds. Data on Arabian and Iranian oil indicate that the oil spilled from the Amoco Cadiz had between 30 and 35% aromatics and 50-83% paraffins, or saturated hydrocarbons (Spooner, 1978). Toxicity of oil depends first upon its composition, and therefore there is no reason to believe the Ixtoc I oil to be more toxic than, for instance, the Amoco Cadiz oil. Other oil spills, involving fuel oil, gasoline or jet fuel, caused more damage to marine life since the lighter fractions of petroleum are more toxic (Sanborn, 1977).

Ixtoc I oil underwent a considerable amount of weathering before landfall in Texas. Figures 3 and 4 show the composition of Ixtoc I oil forty hours after the spill, and oil collected by the USCG Pt. Baker at 22° 50'N and 96° 26'W. This is a point not reached by the oil until July 24, 51 days after the blowout. The most common constituents of the 40-hour oil are saturated hydrocarbons of fewer than 14 carbons and various naphthalenes, also of low molecular weight. After weathering, these components almost disappear. Saturated hydrocarbons in the 17 to 20 carbon range are the most common, along with higher order aromatic compounds. Thus the first compounds removed by weathering (a term that includes evaporation, photooxidation and biodegradation) are the most common and most toxic to life.

From the distance which Ixtoc I oil had to travel before its landfall on Texas beaches, one must conclude that its most toxic components were probably first removed by weathering. The sheer amount of oil continuing to be spilled indicates that the toxic effects near the well are probably severe indeed. In addition, much of the oil must settle onto sediments not far from the well, making nutrients from the bottom unavailable for much of the marine life in the area. How large an area will be so affected is not known, but if other spills are any indication, it could be several years after the flow is stopped before newly deposited bottom sediments again support a variety of marine life (Moore and Dwyer, 1974).

Recent reports by the Texas Department of Health Resources indicate that so far fishes and shrimps from Texas waters are not being contaminated by Ixtoc I oil (Munoz and Sherry, 1979). Continued sampling over a wide area will provide valuable information on the movement and persistence of oil molecules in biological systems.

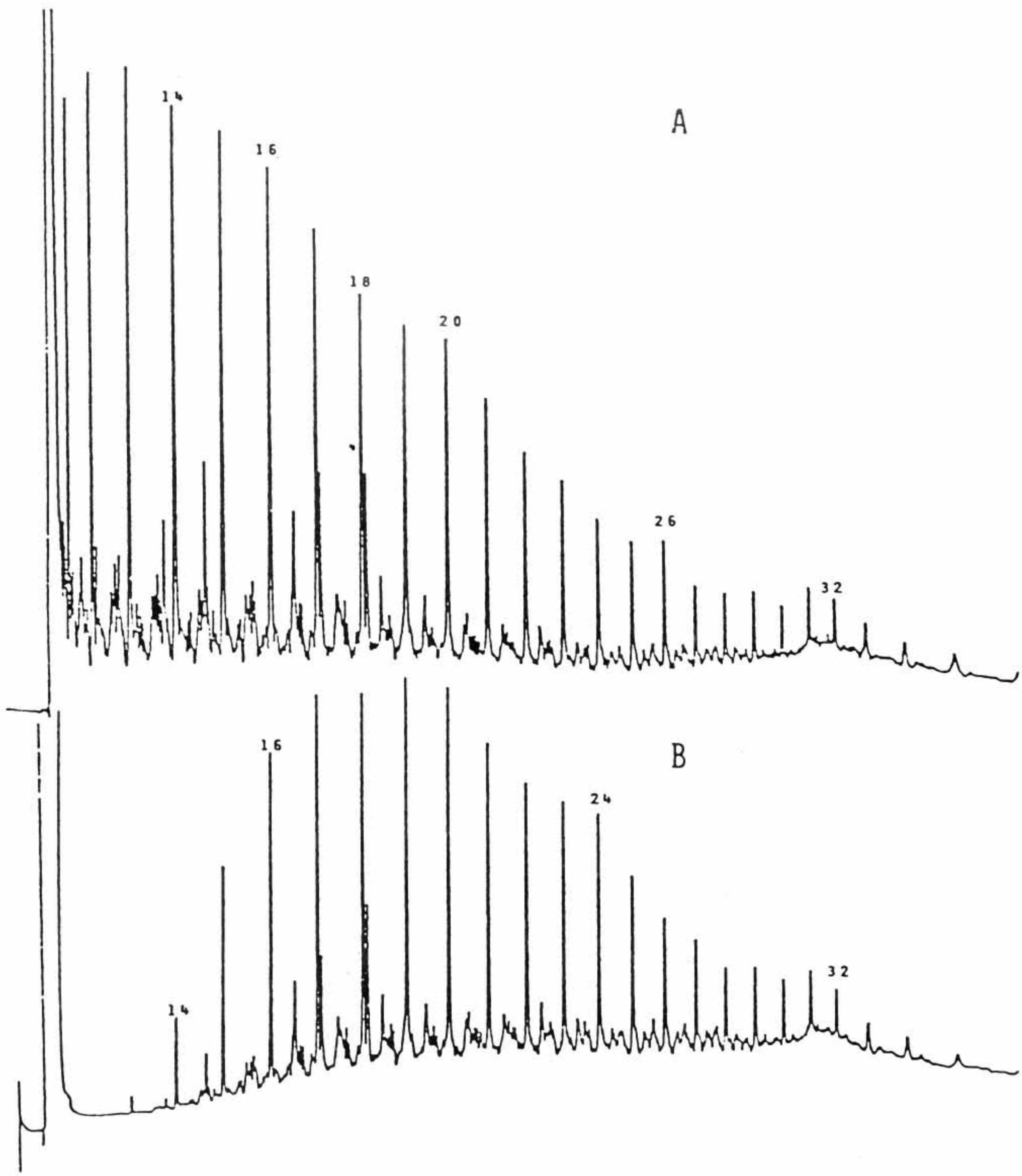
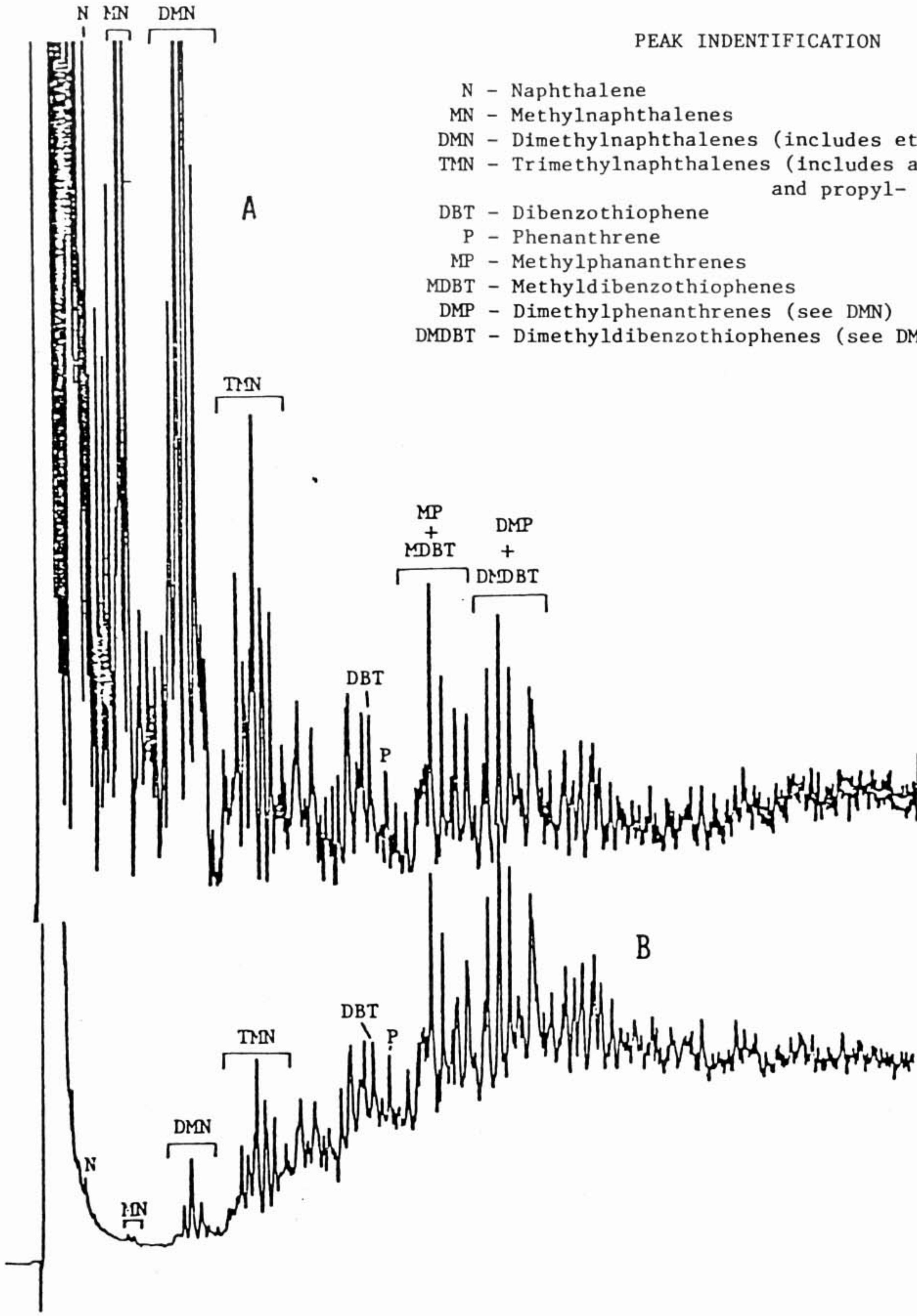


Figure 3. Gas chromatograms of the saturate fraction of a mousse sample collected 40 hrs after the IXTOC I blowout (A), and the Pt. Baker mousse (B). (Figure from Parker et al., [1979]).



PEAK INDENTIFICATION

N - Naphthalene
MN - Methylnaphthalenes
DMN - Dimethylnaphthalenes (includes ethylnaphalenes)
TMN - Trimethylnaphthalenes (includes all methylethyl- and propyl- naphathalenes)
DBT - Dibenzothiophene
P - Phenanthrene
MP - Methylphananthrenes
MDBT - Methyldibenzothiophenes
DMP - Dimethylphenanthrenes (see DMN)
DMDBT - Dimethyldibenzothiophenes (see DMN)

Figure 4. Gas chromatograms of the aromatic fraction of a mousse sample collected 40 hrs after the IXTOC I blowout (A), and the Pt. Baker mousse. (B). (Figure from Parker et al., [1979]).

DAMAGE ASSESSMENT

The sooner expert studies are started the better the position there is to establish a basis for later studies with an ability to detect differences that occur.

The Federal statutes[14] require that a damage assessment be prepared to evaluate the damage to the resources of the northwest Gulf of Mexico as a result of the damage from the IXTOC I oil spill.

The objectives of the management structure of the Damage Assessment Plan established are:

1 - identify and quantify the biological, ecological, and economic impacts reulting from the IXTOC-I oil spill.
2 - Produce a series of reports which will make data and information generated under (1) above available to decision makers in a useful and timely manner.
3 - develop techniques, procedures and methodologies applicable to future interagency/state assessments of damage resulting from spills.[15]

The first proposal to fulfill these objectives developed by the Federal Government seemed designed for projects by the Federal Government. The state's scientific capabilities were not to be implemented and as a result the proposal was not enthusiastically accepted by most of the State of Texas agencies. Texas has many well-trained scientists, engineers, planners, researchers and managers to whom Texas and the Federal government should be turning for help to rescue our Texas beaches and bays.

The management structure is currently being reviewed and while general overview and guidance will be accomplished by the agencies at the Washington level, operations and studies will be completed locally. This working management should provide a Washington input without hindering local response activities. A draft is currently being developed which will serve as the basis for the formal program. The National Oceanographic Atmospheric Administration (NOAA) has made a supplemental budget request for funds for the damage assessment but to date the funds have not been made available.[16]

BLOWOUT PREVENTION

It is not certain what caused the blowout of IXTOC I on June 3, 1979. PEMEX, the Mexican national oil company, said that the blowout was caused by a loss of drilling "mud" which occurred while the crew was attempting to remove the inner drill tubing and bit from the hole.[17] (Mud is the liquid that is circulated through the wellbore during rotary drilling and workover operations)[18]

Testifying before a joint hearing of the United States Senate Committees on Commerce, Science, and Transporation and Energy and Natural Resources on December 5, 1979, Jerome Milgram, a professor of ocean engineering at the Massachussets Institute of Technology and an inventor of oil spill cleanup equipment, said that efforts to kill the well were halted when "it was observed that gas and oil were coming out of the seabed in the vicinity of the well, indicating a lack of integrity of casing structure. The pressure required to pump the mud at this time was very high.."[19]

Testifying before the same committee, Donald Kach, Chief of the USGS conservation division said that by USGS standards, mud supplies were inadequate on the rig and that there was a question about the experience and qualifications of the Mexican drilling crew.[19]

At the same hearing, Stephen Mahood, SEDCO, executive vice-president, said PERMARGO (a Mexican drilling firm) which held two long-term PEMEX offshore drilling contracts, leased the SEDCO rig. PERMARGO also contracted for a few SEDCO personnel. "No SEDCO personnel participated in the decision making process or had access to the geological data upon which PEMEX based its judgments pertaining to the drilling of the well", Mahood said. "All SEDCO equipment that was provided was operating properly."[19]

On October 16, 1979, the Texas House Committee on Environmental Affairs held a public hearing in Austin to find out what standard and customary measures are taken to prevent blowouts in Federal and State waters.

A blowout is the direct result of a "kick". A "kick" is an intrusion of a formation of fluid.[18] Blowout Prevention schools are required by the USGS of companies drilling in federal waters. The USGS requires that everyone involved in the operation of the well should know the procedure for killing a well and be certified annually. The USGS also requires mechanical blowout preventers, pressure monitoring systems, well casing specifications and weekly tests of equipment and procedures.[20]

Jim Herring of the Texas Railroad Commission testified that the oil and gas division of the RRC exercises control of those wells drilled within state waters and is not involved with drilling beyond the 12-mile limit. The Commission has operational requirements designed to keep oil spills from occurring, but does not now require that personnel attend blow-out prevention schools.

Mr. Bruce Damron, Instructor at A&M University, testifying before the committee emphasized that one way to prevent kicks would be to make it mandatory for "trip tanks" to be placed on all rigs.

A trip tank involves a calibrated tank used for the monitoring of mud volume used to replace the steel volume of the drill pipe when pulling the drill string from the wellbore.

The trip tank is only used for the monitoring of mud volume when pulling out of the hole. These tanks are generally calibrated to five barrels and fill the hole by gravity feed.

When the drill pipe is being pulled from a wellbore, the hole experiences a reduction in bottom-hole pressure, due to the interaction, or friction between the drill pipe and mud, known as the swabbing pressure. If the pressure reduction is great enough, a volume of formation fluid can be allowed to blow into the wellbore. This volume of fluid allowed into the wellbore is monitored by the trip tank. The intrusion of a formation fluid is a potential hazard to the drilling operation and, if encountered, the drill pipe that has been pulled, should be run back into the hole and the intruding fluid circulated out, before it becomes a hazard.

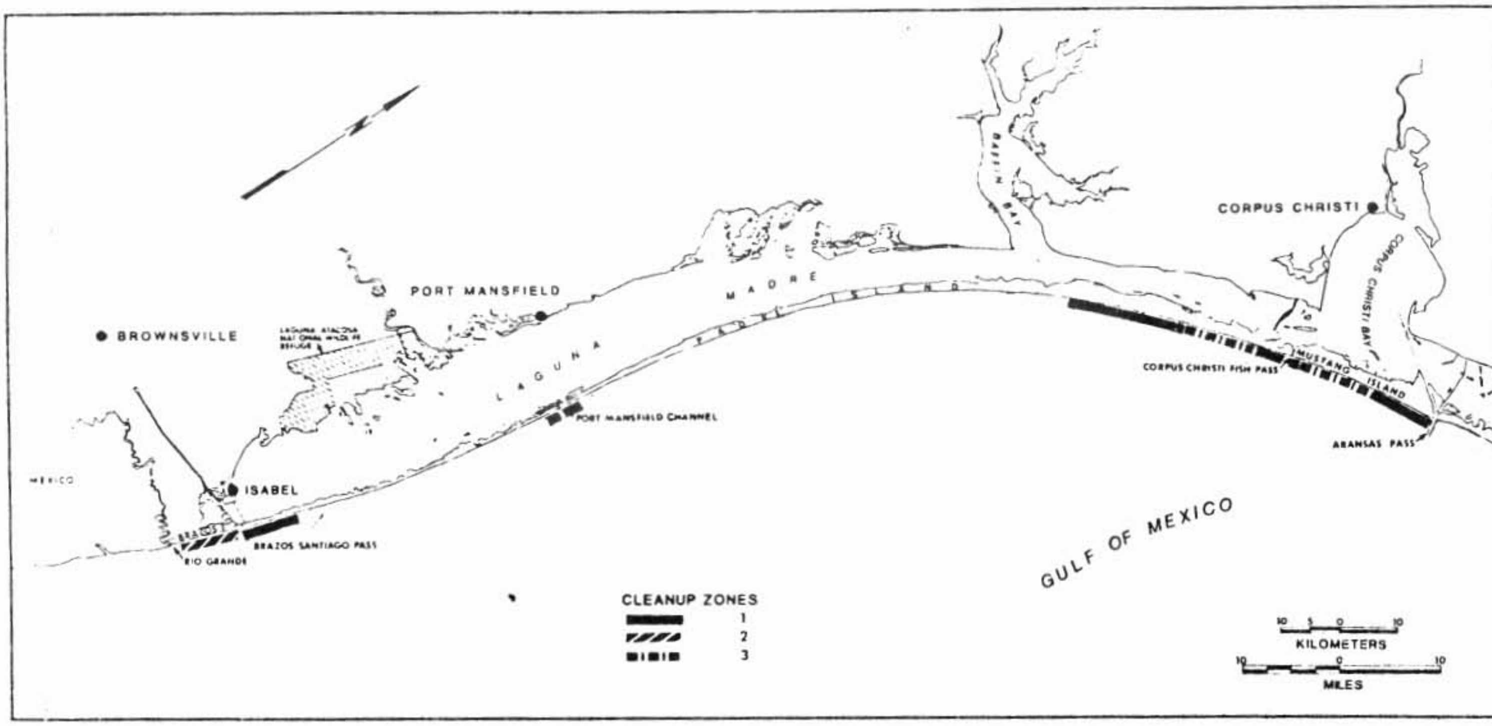
The trip tank allows the operator to determine exactly how much is being placed in the hole, versus a known volume of steel.[21]

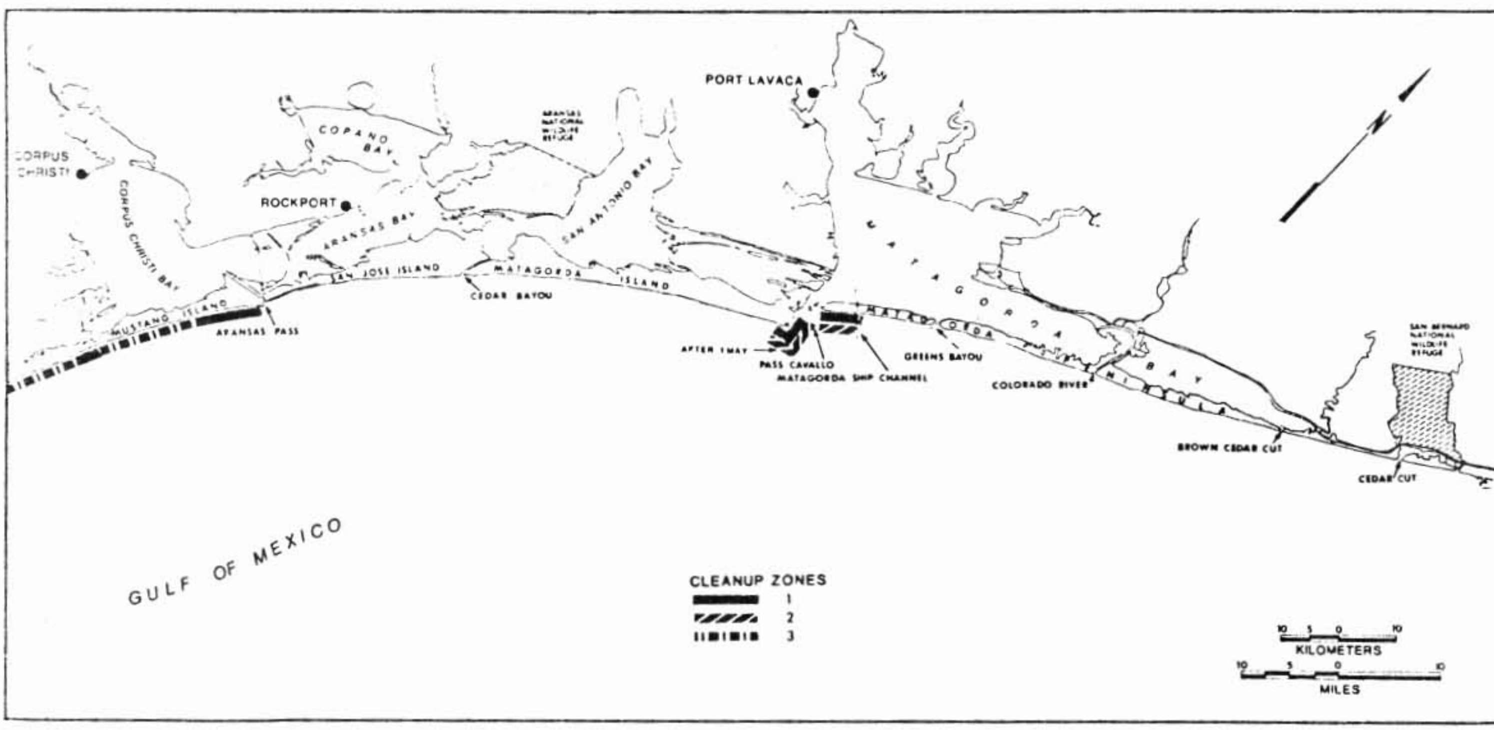
CLEANUP MEASURES

The oil from the IXTOC well arrived in the form of tar balls around the 7th of August. When the oil arrived the Coast Guard Open Water Oil Containment and Recovery System (OWOCS) was in place, together with backup booms and skimmers. Cleanup crews used vac-alls, graders, and front-end loaders to scrape the oil from the beaches. As indicated earlier in this report, the policy of the RRT was to keep the oil out of the bays and estuaries and to use the barrier islands as a natural boom. The oil on the high use beaches was removed as quickly as possible and the other beaches were left to naturally biodegrade. To date the U.S.C.G. has removed 13,757 cubic yards of oiled sand and tar balls, 46,975 gallons of an oil/water emulsion, and 55,080 pounds of oiled debris.

Criticism arose from the policy of the RRT especially from Dr. Roy Hann from A&M University. He felt that if the oil was left on the beaches, cleanup at a later date would be more difficult because the oil would mix with the sand and seaweed. Hann felt if the oil was not removed from the remote areas, storms and tides would redeposit the oil on other Texas beaches. Dr. Hann prepared for this committee an extensive proposal entitled "Potential Components of a More Effective Oil Pollution Control Program for the State of Texas."

While the most practical and short term solution of oil on the beaches is to remove the oil from the sand, the most ecological method is the cleaning of the sand which is a long-term process. The committee has heard testimony to the effect that it is increasingly dangerous to remove sand from an already eroding beach line. During the cleanup operation reports were received that cleanup crews were removing up to six inches of sand when it was only necessary to remove two inches. The unnecessary removal of sand diminishes the Gulf beaches which are a public resource. Dr. W. L. Fisher, Director of the Bureau of Economic Geology at Austin submitted a report to the Texas Department of Water Resources which covers the feasibility of using beach cleanup materials (a mixture of oil and sand) for dune nourishment and stabilization.





LEGEND

Zone 1 - Cleanup should take place when oil coverage in the intertidal region reaches 15%.

Zone 2 - Cleanup should take place when oil coverage in the intertidal region reaches 85%.

Zone 3 - Cleanup at the discretion of OSC.

BEACH CLEANUP ZONES

On January 29, 1980, an advisory board consisting of Federal and State agencies as well as personnel from the Research Planning Institute met in Corpus Christi to reevaluate measures to be taken if the oil from the IXTOC well once again threatened the beaches of Texas. The consensus of this group was:

"It is proposed that a conservative approach be taken to beach cleanup during periods of chronic oil impact. Cleanup operations should be based on economic considerations as well as the physical and biological characteristics of the shoreline. In those areas where cleanup is undertaken, the methods employed should be practical from both a physical and economic perspective."[22]

The Advisory Board recommended that major cleanup activity should be concentrated in regions of high recreational usage or areas in close proximity to entrances through the barrier island system. Lower levels of cleanup are indicated for areas of moderate recreational usage, however, for the majority of the coastline no cleanup is recommended during periods when impacts may be expected to continually occur.[22] (See Chart, p. 65)

Dick Whittington, in a letter to Captain Gerald Hinson, OSC, on behalf of the Texas Disaster Council, stated that "cleanup should be extended to include areas where a single impact occurs with no anticipation that another impact will occur and to areas where oiling occurred on multiple days but has finally ceased and where it will not recur ever or for an extended period of time."[23]

FEDERAL/STATE LOCAL POLICIES

The U.S. Water Quality Act of 1977[2] created a national contingency fund to pay for cleanup costs; and does not cover economic damages. The Federal Small Business Association makes long-term, low interest loans available both for physical damage to private property and economic injury to private businesses.

The State Disaster Act of 1975[4] authorizes state agencies to accomplish whatever is necessary to alleviate the effects of any disaster including oil spills. The Disaster Act does permit "arms length" assistance to local governments and individuals when assistance for physical damage is authorized by the federal government. The state is limited to 25% of the federally approved grant which cannot exceed a total of $5,000 per individual. This program does not cover economic injury or loss of income, thus is not applicable to the oil spill. Local governments have the same authority as the state under the same statutes, except for the physical loss program.

If the oil that hit the Texas coast had been from a tanker that had coverage from TOVALOP or CHRISTAL, the economic, as well as cleanup charges, would have been paid. TOVALOP stands for Tanker Owners Voluntary Agreement concerning Liability for Oil Pollution. CRISTAL stands for a Contract Regarding an Interim Supplement to Tanker Liability for oil pollution.[24]

Pending in the U.S. Congress is a fund called the Comprehensive Oil Pollution Liability Compensation Proposal (Superfund). This fund would provide compensation for spills in U.S. waters. In addition to covering spills from ships and barges it would cover spills from terminals, pipelines, refineries, drilling rigs, production platforms, and deepwater ports.[24]

The primary objective of oil spill legislation is pollution prevention; secondary objectives should ensure that governments, businesses and individuals, within constitutional restraints, are reimbursed for severe economic losses in the case of public calamities. The Committee is currently studying compensation programs established in Maine and Florida, that use a state pollution fund to reimburse citizens and businesses. The current Texas Coastal Protection Fund is limited to a narrow field of cleanup costs and related activities.

The legislation that the committee is currently considering would provide an easily accessible source of money for the cleanup costs, and would reimburse public and private entities for losses.

Several options for funding are being reviewed. Other states raise money from registration fees, or by various taxes. The current Texas Coastal Protection Fund has a ceiling of $5,000,000, while it actually contains $500,000 appropriated by the legislature.

SHRIMP/FISHING INDUSTRY

In a news release, dated November 21, 1979[25], the Texas Parks and Wildlife Department stated that "the environmental impact of oil from the Mexican well in Campeche Bay has for the most part been minimal on Texas fish and wildlife resources." The release went on to say "Based on information now available, there is no evidence of noticeable damage to Texas fish or wildlife other than possibly redfish larvae as a result of the oil spill."

But in a letter dated November 5, 1979 [11] from Charles Travis, executive director of the Texas Parks and Wildlife Department, to Rep. Bennie Bock, Chairman of the Committee on Environmental Affairs, Travis stated that "An oil spill of the magnitude of IXTOC-1 could be devastating to fish and wildlife populations along the Texas coast and the Texas portion of the Gulf of Mexico". "Sports and commercial fish and other aquatic organisms will have sustained the major damages to fish and wildlife", wrote Travis.

The Department continues to be concerned about the impact on the red drum which spawn in the shallow Gulf near passes from mid-August through November, when the heaviest oil pollution occurred in the Gulf. After fertilization, the eggs float to the surface until they hatch in about 72 hours. The eggs do not die after contact with the mousse, but a high percentage of the larvae produced are deformed at the time of hatching. The presence of oil during the period of red drum spawning could have affected the 1979 reproduction on the Texas coast.

"Shrimp represents the most valuable fishery of the state and nation..." stated Ralph Rayburn, executive director of the Texas Shrimp Association. "Should the oil leaking from IXTOC I cause significant damage to the shrimp resources, not only will a multi-million dollar a year industry fall, but also a vital link in the marine food web will be removed."[26]

Dr. Addison Lee Lawrence, Director of the Department of Wildlife and Fisheries Sciences at the Texas Agricultural Experiment Station, stated in his draft proposal for a Data Assessment Plan, dated October 16, 1979, that "the potential effect of the oil on the reproduction potential of the commercial shrimp should be evaluated because:

1. a decrease in the reproductive potential of the commercial shrimp would produce a dramatic and significant reduction of the shrimp populations in the Gulf of Mexico; and
2. the maturation-reproductive phase is the most sensitive biological event in the life history of living organisms to changing environmental conditions."[27]

TOURISM

The news media coverage at the time of the IXTOC I oil spill persuaded the public to stay away from the Texas beaches even before the oil actually hit the coast. Normally in August, the Texas beaches are prime tourist attractions bringing in millions of dollars in revenue. Through the efforts of the Federal, State and local governments, as well as the private sector, most of the oil was successfully removed from the beaches in time for the Labor Day weekend but the impression was already formed and the tourists did not come. Economic losses were heavy from Galveston to South Padre Island. South Padre Island was especially hard hit, according to Frank Hildebrand, executive director of the Texas Tourist Development Agency. Lost revenue there was between $16-20 million. The middle coast also suffered severe damage. The upper coast around Galveston was affected adversely by oil from the ruptured tanker Burmah Agate.[28]

Hotel/motel revenue from the calendar quarter ending September 30, 1979, estimated losses in room rentals for the period was 25%. The loss in revenue was incurred during the last three weeks in August. The oil spill and the resulting publicity caused occupancy to drop from 100% to less than 30%, according to Ralph Thompson, executive vice president of the South Padre Island Tourist Bureau.[29]

The long term effects of the oil spill and the publicity it generated has not yet been determined. As long as the IXTOC I well remains uncapped the beaches of Texas could once again become polluted this spring when the currents turn north again. The economic losses would even be more substantial because an entire tourist season could be affected rather than just a three week period.

SUMMARY

Since June 3, 1979, thousands of barrels of crude oil have been spilling into the Gulf of Mexico. Daily reports continue to indicate that the well will be capped "soon". In the meantime Texas has lost millions of dollars in tax revenues, lawsuits have been filed and both real and potential damage to the fish and shrimp is largely unknown. The question that arises again and again is, can a spill of this magnitude reoccur? Future spills are entirely possible because of the amount of drilling that is being done. IXTOC I was only one of 18 wells being drilled in the Bay of Campeche. We hope to learn lessons from this tragic waste so we can cope with, or prevent future spills.

Oil spills have disastrous affects on both manmade and natural resources. Damages can be high for inhabitants of coastal areas, on the tourism industry, and on the fishing industry. The National Academy of Sciences divides the natural or ecological impacts into five categories:

1 Human hazard from ingesting contaminated food
2 Damages to fisheries, seaweed, birds, marine mammals, and other wildlife
3 Damages to beaches and other recreational areas
4 Damages to the marine ecosystem by eliminating or decreasing populations of certain species
5 Modification of habitats[30]

The damage assessment plan under the auspices of NOAA is still awaiting funding; little work can be done by the federal government until the appropriations are made. It has been suggested that the Texas legislature obtain the necessary appropriations to furnish its own damage assessment program. Studies, whether undertaken by the state or by the federal government, should be built upon existing Texas Coastal research and should utilize available on-site facilities and laboratories. This report has furnished a workable comprehensive oil spill profile by categories and a fish/shrimp species profile, documented baseline data relating to the effects of oil and the reproductive and spawning cycles as well as a regional food web of commercial fishes, shrimps, crabs, oysters and man.

The IXTOC I blowout occurred in Mexican waters and Texas has little control of international waters. An international commission utilizing the blowout prevention techniques of the U.S. government and responsible for keeping individuals in the industry apprised of advanced blowout techniques would greatly mitigate the possibility of another blowout.

In the event that a spill should reoccur either from a blowout on a rig, or a tanker collision, better and more immediate means of cleaning the beaches should be initiated. All avenues of cleanup measures should be investigated including the development of cooperatives between the industry and local authorities. Equipment should be made more readily available on a short-notice. Time is vitally important during the initial crisis.

Compensation policies should be carefully reviewed and evaluated so that help can be readily available to those suffering severe damage. Existing federal and state law do not cover the victims of the IXTOC I spill, since the spill occurred outside federal waters.

IXTOC I is the largest oil spill ever recorded. The Coast Guard expended, through February 28, 1980, $7,612,659.92 in the cleanup effort.

The U.S. Coast Guard, the Regional Response team which includes the Texas Department of Water Resources, and the other state agencies and universities involved in the oil spill response should be commended for their fine efforts. In retrospect, the oil spill has caused much reevaluation of the available procedures, additional prevention measures as well as cleanup techniques that are presently utilized by the state.

COMMITTEE RECOMMENDATIONS

1. The State Contingency Plan should establish specific priorities for action in the event of a spill endangering Texas bays and estuaries.

2. The State should study the cost effectiveness of purchasing its own coastal defense equipment and encourage the creation of an oil industry cooperative to combat spills. Texas should participate in and encourage the development of local spill cooperatives similar to the Corpus Christi Spill Control Association. The government and industry should pool their manpower and equipment in the case of a major spill and become a strong defense against the spill.

3. Form an oil spill advisory group with representatives of government, the oil industry, the fishing industry, the tourist industry and other related interests. The group would develop recommendations and become involved in oil spill contingency planning and response.

4. Encourage the use of state universities in the coastal area for blow out prevention training schools.

5. The committee should study legislation to provide a fund, similar to TOVALOP or CRISTAL, that would cover the costs and damages resulting from oil spills. The current Texas Coastal Protection Fund covers only the cost of cleanup. The IXTOC I oil spill indicates that many other areas may need financial aid to deal with the effects of a major oil spill.

6. The Texas legislature should pass a resolution encouraging the federal government to create an international commission composed of all states bordering the Gulf of Mexico. The purpose such a commission would be to protect those states from the damages of spills, as well as prevention.

7. Encourage federal officials to use the services of Texas scientists, engineers, planners, researchers and managers for closer interaction in addressing the Mexican oil spill related problems.

8. The committee supports Attorney General Mark White in his efforts to collect damages from the proper, responsible, and liable parties involved in the oil spill.

AGENCY RECOMMENDATIONS

TEXAS DEPARTMENT OF WATER RESOURCES:

The following is a brief description of the problems encountered or perceived by the Department's personnel in their response efforts regarding the Bay of Campeche Oil Spill and their recommendations for correcting the problems.

1. A definite need exists for 4-wheel drive vehicles for beach impact and cleanup surveillance. In addition, based upon the past experiences of the TDWR representative to the OSC, such vehicles are not readily available. Consequently it is felt that the Coast Guard should make arrangements to secure such vehicles on a permanent basis so they will be available on short notice when they are required.

2. The various state agencies which have a legitimate interest in oil spills and response activities are not consistently able to obtain up-to-date, understandable, concise information regarding major beach impacts, cleanup activities and the northermost extent of significant impact. Consequently, the Department's representatives to the OSC had to spend significant amounts of time collecting and passing on such information to interested parties. The information should be incorporated into a simple, readable fashion into the Pollution Reports which are put out by the Coast Guard and widely distributed to the state agencies.

3. A great deal of emotional local interest (in some cases opposition) developed regarding the removal of oiled sand from the beaches, the ultimate disposal of such oiled sand, and the need for sand replacement. The following actions may help to alleviate the problems:
   a) conduct research into the beach building/eroding phenomena;
   b) conduct local public meetings prior to the beginning of the 1980 spill response campaign to determine local views so that response activities could be modified accordingly.

4. The TDWR supplied the Coast Guard with pass protection plans. The plans lacked current detailed information on shoaling, current fluctuations, volumes of water passed, existing structures, etc., because the information was not available. Much of the information had to be generated on the spot under duress. When funds become available, the TDWR plans to generate and maintain such data. The Coast Guard should pursue this vital aspect of spill contingency planning as well.

5. The TDWR believes that research should be conducted and equipment developed in regard to sand cleaning and foul weather operations. During the 1979 spill response several unusual phenomena were encountered such as the sinking of the oil, creation of sunken tar mats in the sub-tidal zone, inability to cleanse oiled sand and deficiencies in foul weather operations.

GENERAL LAND OFFICE:

1. The General Land Office should maintain a list of sites on state land that can be used for temporary storage of oil spill material. The Land Office should draw up construction guidelines for each site with the size, levee specifications, drainage provision and access roads. These preparations would allow a timely response to both local spills as well as spills the size of the IXTOC I.

2. Although back-dune areas have not yet been used for storage, guidelines should be developed for temporary storage behind dunes.

3. The contingency plan should take into account seasonal effects. An oil spill during the waterfowl nesting season, for example, could endanger rookeries. Measures for protecting rookeries should be developed.

DEPARTMENT OF PUBLIC SAFETY (Disaster Emergency Services):

Amend the State Disaster Act to authorize an appropriation to DES which could use the funds to contract with cities and counties for the provision of necessary public and private disaster related relief.

FOOTNOTES

1. Federal Register/Vol. 44, No. 94, May 14, 1979. National Oil and Hazardous Substances Pollution Contingency Plan, 40 CFR 1510.

2. Federal Clean Water Act of 1977, Section 311.

3. Texas Water Code, Subchapter G.

4. Texas Disaster Plan, issued in accordance with the Texas Disaster Act of 1973, 63rd Legislature.

5. Coast Guard Captain Roger Madson. Testified before the Texas House Committee on Environmental Affairs, Corpus Christi, August 24, 1979.

6. Dick Whittington, Deputy Director of the Texas Department of Water Resources. Statement to the Regional Resonse Team meeting in New Orleans, Lousianna, July 13, 1979.

7. Dick Whittington, Deputy Director of the Texas Department of Water Resources. Testified before the Texas House Committee on Environmental Affairs, Corpus Christi, August 24, 1979.

8. Wilson Speir, former director of the Texas Department of Public Safety. Letter to Committee Chairman Bennie Bock dated September 24, 1979.

9. Bob Armstrong, Commissioner of the General Land Office. Material furnished to the Committee, October 3, 1979.

10. Neil Travis, Director of Shellfish Sanitation Control of the Texas Department of Health. Letter to Nevenna Travis of the Texas System of Natural Laboratories dated December 14, 1979.

11. Charles Travis, Executive Director of the Texas Parks and Wildlife Department. Letter to Committee Chairman Bennie Bock dated November 5, 1979.

12. Texas System of Natural Laboratories Report to the Committee on Environmental Affairs, January 15, 1980, p. 8.

13. Ibid, p. 5.

14. National Oil and Hazardous Substances Pollution Contingency Plan, Section 151022.

15. NOAA and Fish and Wildlife (DOI) draft report Start Up Strategy and Management Structure for the Proposed Assessment Program attached to letter to Texas Governor William Clements from NOAA Deputy Administrator James P. Walsh dated January 16, 1980.

16. Judith Roales, NOAA. Statement at the Regional Response Team Meeting in Corpus Christi, January 28, 1980.

17. Joseph Albright, Austin American Statesman. Newspaper article, September 9, 1979.

18. Bruce Damron, Instructor at Texas A&M University. Testified before the Texas House Committee on Environmental Affairs, Austin, October 16, 1979.

19. "Pemex slapped for handling of 1 IXTOC," Oil and Gas Journal, December 17, 1979.

20. Federal Register, Vol. 43, No. 39, p. 8040-1. Geological Survey Training and Qualifications.

21. Bruce Damron, Instructor at Texas A&M University. Letter to Committee dated November 7, 1979.

22. John H. Robinson, Scientific Support Coordinator, NOAA. Letter to Captain Gerald C. Hinson, Federal On-scene Coordinator, U.S.C.G. dated February 5, 1980.

23. Dick Whittington, Deputy Director of the Texas Department of Water Resources. Letter to Captain Gerald C. Hinson, Federal On-scene Coordinator, U.S.C.G. dated February 15, 1980.

24. James J. Reynolds. Article Oil Spill Liability and Compensation (Superfund). Proceedings of the Oil Spill Conference, March 8-10, 1977, New Orleans, La., p. 15. Sponsored by the American Petroleum Institute.

25. Texas Parks and Wildlife Department newsrelease on oil spill damage dated November 21, 1979.

26. Ralph Rayburn, Director of the Texas Shrimp Association. Letter to Nevenna Travis, Texas System of Natural Laboratories dated January 4, 1980.

27. Addison Lee Lawrence, Professor, Department of Wildlife and Fisheries Sciences, Texas Agricultural Experiment Station and Extension Service. Draft proposal Determination of the Potential Effect of the Ixtoc I Oil Spill on the Reproductive Potential of Three Species of Penaeid Shrimp dated October 16, 1979.

28. Frank Hildebrand, executive director of the Texas Tourist Development Agency. Letter to Nevenna Travis, Texas System of Natural Laboratories dated January 9, 1980.

29. Ralph Thompson, executive vice-president, South Padre Island Tourist Bureau. Letter to the committee dated November 30, 1979.

30. National Academy of Sciences, 1975. Petroleum in the Marine Environment. Washington, D.C.

APPENDIX A

POTENTIAL COMPONENTS

OF A MORE EFFECTIVE

OIL POLLUTION CONTROL PROGRAM

FOR THE

STATE OF TEXAS

Prepared by

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December 1979

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Dr. Roy W. Hann, Jr.
December 1979

INTRODUCTION

Texas, a state with a long history of living in harmony with the oil industry, has suffered an incredibly bad year with regard to oil pollution of its bays, estuaries, ship channels, beaches and coastal waters. The reasons for this influx of oil spills have ranged from acts of God such as lightning striking the SEA TIGER and CHEVRON HAWAII, inadequate technology, as in the case of the IXTOC I, and seamanship problems ranging from the collision of the BURMAH AGATE, the collision of the AMOCO CREMONA with a mooring dolphin and the reported overrun of its own anchor by the ESSO BAYWAY.

There are, however, two common factors which make the likelihood of the repeat of these accidents a real probability. First, the majority of these spills involve foreign oil shipped to Texas to replace our dwindling domestic supply. This is a phenomena of only the last few years but could continue. Secondly, the exploration and production of oil in deeper areas of the sea where problems cannot be solved as quickly or easily.

Perhaps these problems could be tolerated if an adequate response mechanism was in place. Unfortunately, none have been perfect and some have been downright pitiful, allowing hundreds of miles of Texas beaches to be fouled with oil, large areas of our coastal plain were covered with floating slicks and considerable oil was deposited in the subtidal zone near our coast. In addition, many of the decisions being made are not using the experience and capability of Texas scientists and engineers or extensive Texas data bases, nor adequately considering the wishes of Texas state agencies. All resources of Texas agencies and industry have not been utilized. As a result it appears that the time has arrived for Texas to develop a program to assure that effective responses are generated to oil spills which impact on the beaches and subtidal resources it holds in trust for its citizens.

In this document the author reviews a number of lessons learned from selected spills in Texas in the recent past which he has studied in depth.

A program is then proposed for Texas which he believes can capably use the governmental, industry and academic resources in Texas.

RECENT SPILL EXPERIENCES IN TEXAS AND ELSEWHERE AND THEIR LESSONS

A. The IXTOC I: The IXTOC I was the first of the two really major spills that exposed the deficiencies in the existing oil pollution control response mechanism as it exists for Texas. The IXTOC I resulted in approximately 10,000 tons of oil being deposited on the Texas coast in August and September 1979. The spill response was carried out under the auspices of the National Contingency Plan with funding from the National Oil Spill Contingency Fund, inasmuch as the United States was concerned, the spill fell either into the category of mystery spill or one where the spiller refused to accept responsibility for the spill. In the opinion of the author the response left much to be desired.

1. The input to the decision process by Texas agencies and academic community was minimal and particularly the wishes of some State agencies were given little regard in the federally dominated response.

2. No predeveloped plans for the booming of the estuary entrances had been published and, indeed, are not believed to have existed prior to the spill. In spite of the 75-day lead time, no such plans were documented and published, and oil did appear at two of three most southern Texas estuaries before any booms were in place whatsoever.

As an example the Oil Spill Technical Assistance Team of

Texas A&M University, in conjunction with the Brownsville Navigation District had gone into a field a month before the oil hit the Brazos Santiago Pass and carried out an extensive background study including current measurements and potential boom deployments in the Brazos Santiago Pass. Although they advised the current Federal on-scene commander that they were in the field carrying out these studies, and had hand carried the study results to the science support coordinator and discussed preliminary results in person with the on-scene strike force commander, the recommendations were not followed nor were the reasons for choosing an alternate plan presented. Indeed, the person in charge of the response in the Brazos Santiago Pass had not even been made aware of the study or provided a copy of it.

3. Our bay and estuary entrances were protected more by the pelletized nature of the weathered mousse and the normal current characteristics at the end of the jetties which tend to divert sand and thus other particles around the entrance to the estuaries than by protective booming. This was fortunate because all but one boom deployment in the Brazos Santiago and Mansfield Cut areas were placed in current regimes where they could not possibly hold oil against the prevailing currents during a normal tidal cycle. The exception was one boom which would hold under prevailing currents but would fail under nominal wind conditions from the east, the prevailing wind direction.

4. Since large inventories of booming materials were not available in Texas, and thus had to be acquired from Navy or contractor resources adequate booming equipment was late in coming and inadequate in terms of quantity.

5. There was a failure to use industry resources other than the excellent but quite limited capacity of a few oil spill cleanup contractors. In developing plans to deal with the IXTOC I little or no use was made of the extensive resources available throughout the industrial community of Texas.

As the home of the oil industry in The United States, extensive engineering and managerial talent for use on the major oil spills exists in the State and large inventories of equipment are maintained under the auspices of the Clean Gulf Cooperative and its member companies throughout the Gulf Coast region, with the heaviest emphasis in Louisiana. At the time of the IXTOC I spill some 56,000 feet of oil spill control boom was owned and stockpiled by these entities.

6. The most unacceptable component of the response from the viewpoint of the author was the slow rate of removal from the beaches in front of the resort hotels and the failure to remove materials from other beaches. Based on a gross miscalculation of the stability of our barrier island system and of the efficiency of equipment for removing oil effectively from the beaches, decisions were made which allowed oil to remain on the beaches. This decision resulted in the oil becoming further mixed with sand, a major part of it being deposited in the subtidal zone immediately in front of the beaches at the fragile edge of the ocean and other quantities moving elsewhere in the environment, either to other beaches or into the bays and estuaries. Although a reversal in this policy was achieved, by the concerted effort of State agency personnel, the U. S. Fish and Wildlife Service and other groups working through the science support coordinator, the delay in getting the policy reversed led to the oil being so buried on the beaches or deposited in the subtidal zone that further recovery was impossible.

7. The leaving of the oil on the beaches in such large volumes established a dangerous precedent in that others who spill oil off the Texas coast could argue for non-cleanup of their oil on the beaches based on the example of the IXTOC I. This came to pass following the collision of the BURMAH AGATE.

8. Relatively little concern was shown on the federal level except by local Congressmen for the plight of the

individuals who incurred economic damages as a result of this spill. Indeed, there appeared to be those who felt these people should willingly accept economic loss to enhance the negotiations for Mexico's energy. Specific remedial legislation in Congress is being held hostage by those who hope to use the IXTOC I spill to force the passage of the larger and more comprehensive "Superfund" bill.

B. The BURMAH AGATE: The BURMAH AGATE oil spill began with the collision of the freighter MIMOSA and the BURMAH AGATE at the Galveston Bay entrance channel some six or seven miles offshore at Galveston on November 1, 1979. The key issues in this spill were:

1. The failure of the U. S. Coast Guard to adequately monitor the movement of the oil along the coast;

2. A repeat demonstration that contingency plans did not exist for the booming of the bay entrances in the event of such a spill and indeed until impact occurred on the coastline without any defensive measures being in place whatsoever;

3. The spill was the exact situation for which the Coast Guard had developed their offshore containment and removal equipment package over the past nine years, and although the Coast Guard was supposed to be able to respond rapidly to a tanker accident which was spilling oil, the response in this case was exceptionally slow. An initial Coast Guard skimming barrier was not put into operation until four days after the spill, and it failed. Skimming operations using a second barrier and two Navy Marco skimmers did not initiate until eleven days after the spill, and their recovery rates were very disappointing. The Navy's Lockheed skimmer was not yet in use sixteen days after the spill. The excellent weather existing in the Galveston area during much of this period and the fact that in most cases the oil came from the ship in a narrow cohesive stream particularly demonstrates that this

federally owned, offshore containment equipment is no major defense from pollution from an offshore spill.

4. Failure to use industrial resources can again be cited. Again, for various reasons, the substantial offshore pollution control capability of the oil industry on the Gulf Coast was not utilized in dealing with this spill. The Clean Gulf Cooperative has several skimming devices including a fast response skimmer and a large "Hoss" skimming system which were available for use during this spill but were not.

Fortunately, as the spill progressed, some estuarine defenses were developed and deployed to cover further releases from the ship. The failure for fast response to this spill may be partially attributed to the organizational framework under the Federal Water Pollution Control Act which permits the responsible party to handle its own cleanup. The question arises, however, when the person responsible is not able to physically carry out a fast response and the governmental agencies have the capability to do so, whether the government should not proceed immediately to deal with the problem until such time as the industry is able to do so. The assumption of liability and cleanup costs by the BURMAH AGATE and their insurance company is applauded; however, it is believed their interests would have best been served if an organization were available to deal with the problem immediately until help, arranged for by these parties, could have arrived, rather than allowing the oil to flow freely into the environment.

C. The ESSO BAYWAY: The ESSO BAYWAY spill occurred in the Neches ship channel on January 29, 1979. The spill is believed to have resulted from the ESSO BAYWAY overrunning its own anchor in this shallow waterway, when it tried to make an emergency stop to avoid a sinking barge at the Sun Oil docks. The ESSO BAYWAY spill is notable because the company involved in the spill had been carrying out an extensive worldwide marine casualty response program planning activity and as a result, a capable management and contracting team worked together to deal with the spill. The favorable north winds during the spill period enabled the oil to be contained in a relatively small area and the ultimate cleanup was successful. However, southerly winds could have carried the oil into the large marshlands area of the Bessie Heights canal and Grays bayou. The spill exposed the following weaknesses:

1. The lack of an effective oil spill cooperative organization among the industries of the Neches estuary;

2. The lack of an effective oil spill contingency plan for the Neches estuary area;

3. The lack of specific site-specific planning for such areas as estuary entrances on the channel which included plans to close these estuaries and the equipment and personnel available to expedite their closure at the time of the spill.

D. <u>The HEARNE PIPELINE BREAK</u>: The HEARNE PIPELINE BREAK occurred near the community of Hearne north of College Station in early June of 1977. It is mentioned to show that not all of our pollution problems are confined to the coastal zone. In this case a pipeline ruptured and spilled over a thousand of barrels of oil which ran into local creeks. An initial quick response by company personnel in the local area, was effective in containing the oil. Unfortunately, a skilled oil cleanup contractor was not quickly called in to remove the oil and the removal rate by contracted vacuum trucks was slow and ineffective. During the period of the spill removal a major thunderstorm occurred in the drainage basin of one of the creeks causing the creek to rise and currents to increase in excess of entrainment velocities on the booms. As a result, the majority of the oil was swept under the booms, down the Little Brazos River and the Brazos River into the Gulf of Mexico. During the time of the spill personnel from EPA who are in charge of spills in inland areas and the Texas Railroad Commission visited the site but did not stay in constant contact with the cleanup operations. Three major lessons were learned from this spill:

1. Continuous monitoring of the spill response effectiveness is needed;

2. On-scene personnel need to be advised of effective resources to deal with the spill and the potential problems of not using them;

3. The necessity of cleaning the banks of an additional fifty miles of the Little Brazos River (as a result of losing the oil) was a much higher cost than that of bringing in a contractor with effective skimming devices early in the spill.

E. The METULA: The oil spill from the supertanker METULA provided many lessons to those throughout the world who cared to look and consider them. Since no cleanup was attempted, this spill has become a major scientific experiment on what happens when a spill is left to nature. It generally shows that in high energy areas the oil erodes away rather quickly and goes into the marine environment. In sheltered areas, such as protected beaches, supratidal areas and marshlands, the oil can remain for extended periods of time if substantial oiling has occurred. This spill showed us that the already large volume of oil spilled was magnified by the emulsification of approximately two to three parts of water into each unit of oil.

The task of moving this mass of emulsified oil is a public works job of significant proportions. It was this observation that led to the designation of the Texas Department of Highways and Public Transportation as an action agency during the time of the spill since they are an entity which has the manpower and equipment to deal with such a task.

The METULA spill occurred in a very remote area where access and the use of equipment would have been very difficult. It also reminded us that we have such systems in Texas in that access to many of our barrier island systems is limited and that getting equipment to such islands and oily materials from such islands is a problem which must be dealt with effectively in our contingency planning program.

F. The AMOCO CADIZ: Until the IXTOC spill, the AMOCO CADIZ spill of 223,000 tons of oil on the Brittany coast of France was the world's largest oil spill. It also brought forth many interesting lessons, only a few of which will be discussed here.

1. The lesson it again demonstrated was that the major defense for a major spill will be made on the coastline.

2. It again demonstrated that the volume of material to be handled can be increased considerably by the emulsification of the oil and the contamination of sand, seaweed and detritus.

3. The overall effort and cost of cleanup were increased dramatically by failure to act swiftly.

4. There was a failure to have effective site specific contingency plans for the protection of the estuaries and for quick marshalling of forces to remove the oil when it is most amenable to removal.

5. There is a need for an effective overall contingency plan for both the federal administrative level and a local site-specific level.

6. It is also necessary to have a hierarchy of response organizations running from local capability to deal with small spills to major public works and military resources to deal with large spills.

Following the AMOCO CADIZ, the Republic of France has initiated a program which requires its national public works agency, the Department of Equipment, to carry out extensive local site-specific contingency planning. The author has observed some of these local site-specific contingency plans which deal with each beach, each harbor and each estuary of the coasts These include detailed plans of boom deployment, boom requirements, the construction of boom anchorages, beach access, oiled material disposal areas, etc.

SUMMARY

The spills discussed in detail above are but a few from which major lessons can be learned. Detailed reports have been written by the Oil Spill Technical Assistance Team at Texas A&M University on most of the above mentioned spills, but the team is prepared to provide additional information on spills elsewhere which also demonstrate these and other points.

SUMMARY OF SHORTCOMINGS OF THE EXISTING SYSTEM IN TEXAS

The author has viewed the spills discussed above and has tried to develop a summary list of what he considers to be the shortcomings of the existing system, as it relates to Texas.

1. In the absence of an aggressive State program, the system is federally dominated. As a result, decisions are possible, as on the IXTOC I, which are not in the best interest of Texas, e.g. international energy politics with Mexico or the failure to move quickly and effectively with regard to the spill taking place from the BURMAH AGATE.

2. There has been a demonstrated shortcoming in the federal organizational response capability, i.e. the federal response carried out in Texas to date has depended entirely or almost entirely on contractor resources and the limited capability provided by the U. S. Coast Guard and U. S. Navy.

3. There is lack of site-specific local contingency planning. In spite of the charge in the 1970 Federal Water Pollution Act that local contingency planning should be carried out, it generally has not been done in Texas (with the exception of the Corpus Christi area with its local spill control association). As a result when a spill like the BURMAH AGATE occurs off our coast, there is no detailed plan readily available

which shows how to boom certain estuaries or to demonstrate the priority of protection for the different environmental systems.

4. There is a need for preconstructed boom and anchorages in estuary entrances, ferry landings on inaccessible islands for emergency access, preconstructed diversion areas in which to deflect oil, storage facilities, etc, in order to make rapid responses and to be able to respond effectively in remote areas.

5. There is a lack of response capability based in Texas. In spite of the heavy level of marine and oil related commerce and the evolving oil production offshore, the amount of oil pollution control equipment based in Texas is quite limited. The main industrial equipment inventory is maintained in Louisiana, the main contractors working on the Gulf Coast have their headquarters in Louisiana and the limited federal response capability of the Gulf Strike Team is based in Mississippi. Similarly, the Navy capability is based on the east and west coasts of The United States and not in Texas.

6. There is a failure to use existing industrial capability and management in dealing with oil spill response. The carrying out of a major oil pollution response such as to the IXTOC or even a smaller spill, requires the establishment of a response organization with skilled and knowledgeable people in the key areas. On a spill that lasts for an extended period of time, a reserve of such people is necessary so that those involved can cycle back to their old duties and other responsibilities. There exists in the industrial community in Texas either current or potential capability for staffing such response organizations. Indeed, many individuals have been used to staff responses within their companies either in Texas or elsewhere in the world.

7. The federal response in this area is dictated by the Regional Response Team, which has representatives from many federal agencies but only one seat for the State of Texas.

Indeed, the State agency that is represented must have many of its programs approved by the federal government and much of its budget comes from the federal government making the taking of a strong position at cross purposes with the federal administrators very difficult unless backed by a strong state policy group.

Aspects of the Federal Water Pollution Control Act calling for either the subcontracting of certain activities to the State and the repayment of certain State costs incurred at the time of spill makes it possible for a state to take a much more aggressive role if it chooses to do so. A model program exists in the State of Maine.

8. The failure of the U. S. Coast Guard to succeed in making a rapid response to the BURMAH AGATE or other spills indicates that a more rapid response capability needs to be established in Texas.

9. The failure of the U. S. Coast Guard and Navy equipment at sea to attain a meaningful reduction of the pollution level leaving a stricken ship indicates that the State should develop alternate response measures as well as be prepared to deal with the oil on the coast.

10. There has been a substantial use of non-Texas scientists as part of the federal science support program in Texas while at the same time ignoring the years of experience existing in Texas agencies and institutions. The use of such scientists has led to decisions which are at cross purposes to the wishes of Texas agencies and to the beliefs of many specialists in Texas who deal routinely with oil related issues.

11. Failure to establish either policy or decision rationale for cleanup methods, disposal methods, chemicals, sand replenishment, etc., which need be decided before (not during) the spill.

Dr. Roy W. Hann, Jr.
December 1979

STATE OF TEXAS
ALTERNATIVES

Texas is believed to have three alternatives it can pursue with regard to oil pollution control in Texas.

1. Texas can accept the current standard of performance and continue to let the federal government deal with oil spills with only token State participation.

2. Texas can aggressively seek improvements in the federal response structure but with still only token Texas participation.

3. Texas can embark upon a joint state-industry program whereby it is able to establish its own policies for the clean-up of its coastlines and to utilize the management, academic personnel and equipment resources of the local and State government and industry resources to develop the model State program for the protection of its environmental resources.

WHY A GREATER
ROLE FOR TEXAS

It is believed that State action is needed or warranted to achieve a more effective oil spill response in Texas for the following reasons:

1. The State is allowed to assume greater responsibilities and to be repaid for response expenses under the Clean Water Act and the National Contingency Plan.

2. Reasonable local government cleanup costs and third party damages can be reimbursed under international insurance programs.

3. The need for effective site specific contingency plans for Texas bays and estuaries.

4. The need to prepare access to some barrier islands, boom and anchorages, diversion areas and storage areas.

5. The need to stimulate fact efficient response to minimize impact.

6. The need for a reservoir of response equipment in Texas.

7. The need for a trained corps of men for rapid reponse and

supervision.

8. The need to have State policy pre-established regarding what areas are to be protected, where and how to clean, what to use, where to put residue, sand replacement, etc.

9. The need to provide for use of State resources to supplement individual and contractor resources and vice versa.

10. The State superport may require direct State response and industry assistance and,

11. There is a need to carry out tests of response methods for use on Texas environmental systems.

GREATER STATE ROLES
BEING ASSUMED ELSEWHERE

The idea of a greater State role in oil pollution control is not new. A very successful program is being carried out in Maine and the program is being copied to various degrees in New Hampshire, New York and New Jersey.

The Maine program is an entirely state program funded by a State Contingency Fund acquired from a 03¢ per barrel tax on crude oil and products. The fund is currently being raised from $6,000,000 to $10,000,000 with strong industry support.

The program is administered by Mr. Marc Guerin and is staffed with a group of State spill response supervisors. The program role is to either oversee a spiller's cleanup or to step in and clean up the spill if necessary.

The program fund is partially regenerated through response charges paid by spillers.

In Maine the U. S. Coast Guard role shifts from that of complete responsibility to that of being a resource to be called in by the State. The U. S. Coast Guard Division in Boston is reported to be quite pleased with the arrangement.

Although the Maine program is somewhat different from the one suggested for Texas, there are many aspects of the program which are similar. A visit to Maine to explore this program in depth might be valuable for those planning a new program.

ORGANIZATIONAL COMPONENTS
OF A PLAN TO
PROTECT TEXAS

It is suggested that Texas intensively investigate the formation of development of an integrated oil spill response framework for the State of Texas. The key elements of such a plan would be:

1. A stronger State role in policy development using state agency, academic and industrial talent.

2. A stronger State role at the spill time utilizing such techniques as a State Advisory Committee, a State Science Support Team, and a strong State On-Scene Commander and Science Support Co-ordinator. These groups could execute and promote State policies on speed of response, resources to be utilized, methods to be utilized, and results to be achieved.

3. A stronger response mechanism within the State of Texas. These could include the creation (or stimulation) of oil spill co-operatives utilizing state, industrial and federal participation patterned along the lines of the highly successful Corpus Christi Area Spill Control Association. This response mechanism could include State participation in providing the resources and management and staffing for such a response, the establishment of a hierarchy of response using contract, state agency, and industrial personnel, and the development of industry-state agreements prior to spills with regard to the use of State resources on industry spills and ultimately, industry resources on State spills if the State support comes into being.

4. An appropriate financing mechanism to share the burden of cost for the response mechanism and the scientific support could be established utilizing a variety of State and industrial funding mechanisms.

5. The preparation of appropriate legislation to enable the program to provide for State participation in the program, to construct needed State facilities and to provide a source of emergency operational funds until repayment is received from the spiller or the Federal Contingency Fund.

OIL SPILL CONTROL COOPERATIVES DEVELOPMENT IN TEXAS

Throughout The United States there have been developed over 100 oil spill cooperatives. Many have been very effective. They have established a strong equipment and supply resources for dealing with spills. Some provide emergency manpower from a group of government or industrial sources and some carry out intensive response drills and training sessions to prepare to deal with spills. A few are nothing but loose mutual aid societies that have little effect.

The idea of effective oil spill cooperative structure has not developed on the Texas coast. Most existing cooperatives such as those on the Neches Estuary, Houston Ship Channel, Texas City, Freeport area and the Galveston-Lower Trinity areas have limited equipment resources and little or no contingency planning or collective response plan capability. The notable exception is in Corpus Christi. The Corpus Christi Spill Control Association is a unique local government-industrial partnership; each pays half the cost of equipment and for running an effective cooperative capable of dealing with the normal expected problems in that local area.

It is the example of an effective cooperative in this area which demonstrates the pathway to an effective State program to stimulate the growth of the cooperatives in the other areas and to spur through State assistance their improvement.

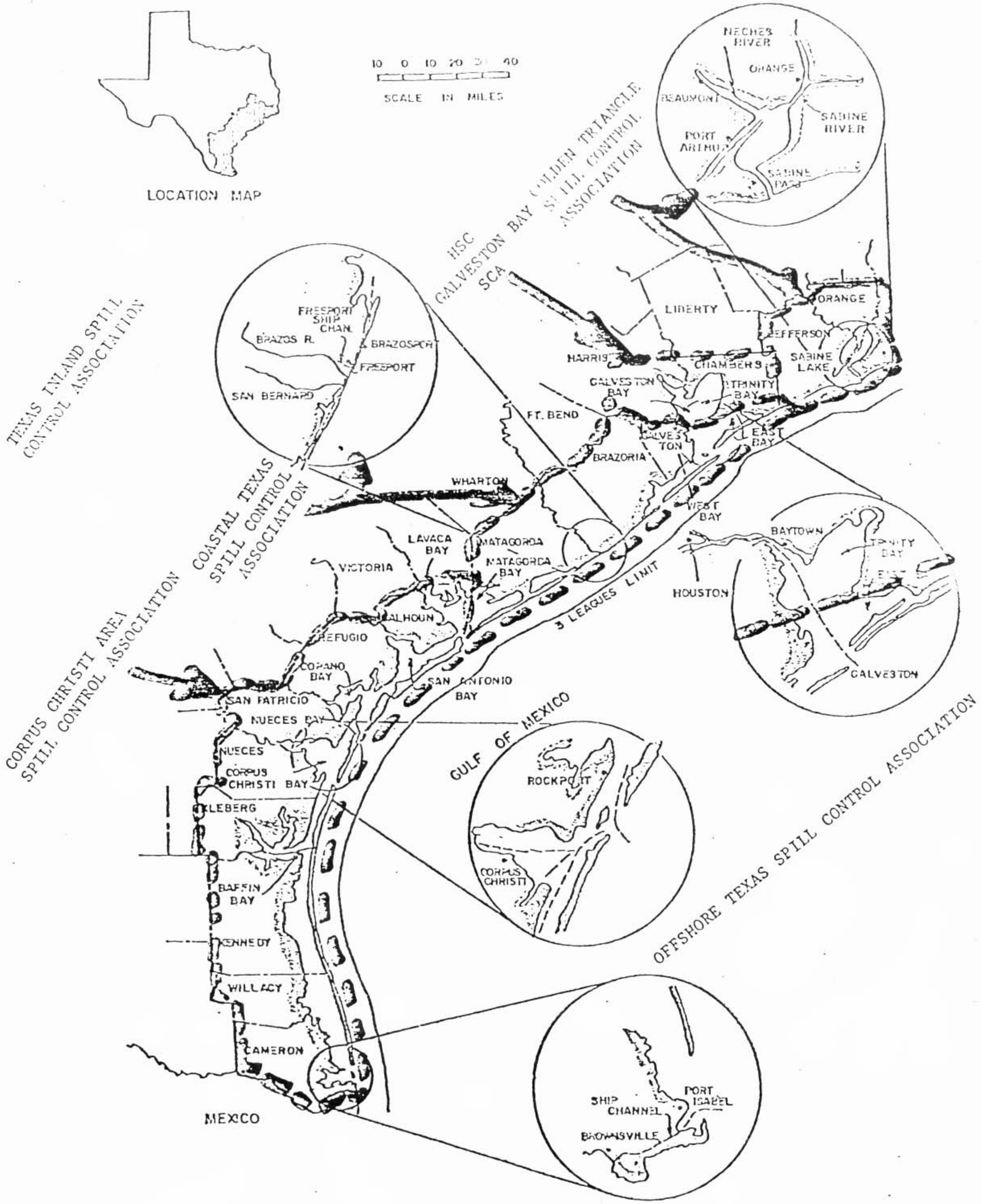
As shown in Fig. 1, it is suggested that a group of five spill control associations be established along the Texas coastline with perhaps a sixth being established in the inland portions of the State. These would consist of the Golden Triangle Spill Control Association, which would cover the Orange, Beaumont, Port Neches, Port Arthur area; the Houston-Galveston Bay Spill Control Association which covers the Houston ship channel, Bayport-Cedar Bayou industrial complex and the upper half of the Galveston Bay; the Coastal Texas Spill Control Association which would cover the Galveston, Texas City, Freeport area and associate coastline; the Corpus Christi Spill Control Association which would expand its coverage from the Rio Grande to Pass Cavallo and the Offshore Texas Spill Control Association which would expand upon the capability of the Clean Gulf Cooperative for offshore operators, but also integrate with this the capability for dealing with marine transportation accidents.

A potential line diagram showing the overall structure recommended in this section and within it these five associations, plus membership by the State in the Clean Gulf Association to gain access to its equipment reserves, is shown in Fig. 2.

It is envisioned that these organizations would be set up as living entities with a core staff to administer the program and maintain cooperative equipment resources and each would have technical support from its member companies or consultants to carry out an effective, aggressive activity of contingency planning for their project area under general guidelines provided by the State of Texas.

The specific activities envisioned for each of the cooperative entities are outlined as follows:

1. To develop both administrative and site-specific contingency planning to deal with anticipated types of accidents in their particular areas.



TEXAS COASTLINE

FIGURE I

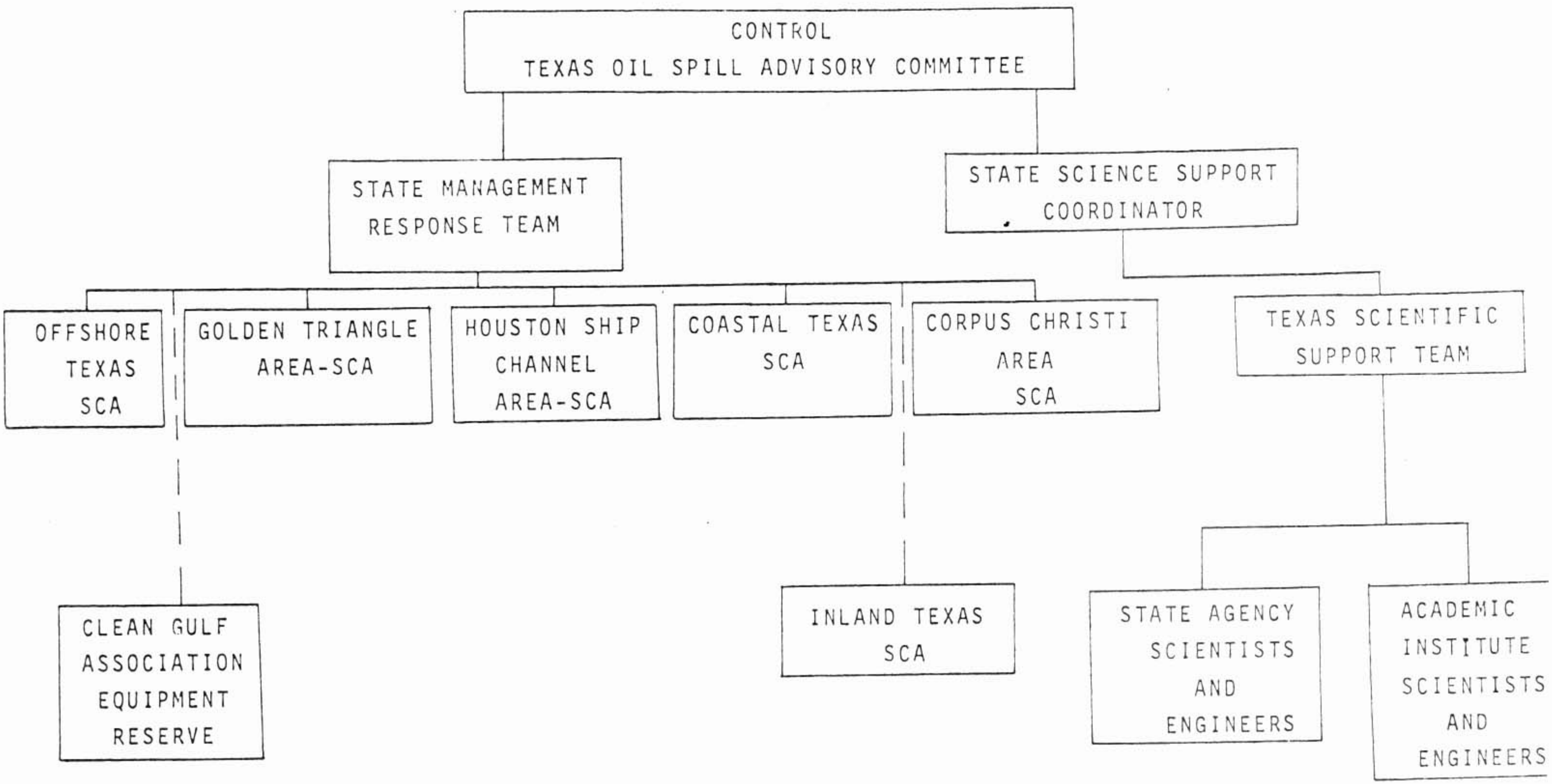


FIGURE 2
POTENTIAL OIL SPILL CONTROL ORGANIZATION FOR TEXAS

2. To construct the necessary facilities, boom anchorages, diversion areas, interim storage areas, long term disposal areas and ferry landings for use during time of spills.

3. To develop and maintain inventory of specialized supplies and equipment for use during time of spills.

4. To develop necessary pre-agreements for governmental agency, contractor and industry response covering the use of manpower, equipment and other resources and further develop agreements with other cooperatives in the State and elsewhere such as Clean Gulf to share equipment in the case of a major spill.

5. To provide an instantaneous management structure to deal with both major and minor spills.

6. To provide either response personnel or initial response personnel until replaced by contractor or spiller personnel resources.

7. To identify participants who will staff both management and operating personnel roles so they can be trained in these activities.

OIL SPILL COOPERATIVE
ADVANTAGES

It is believed that the development and promotion of the Oil Spill Cooperatives by the State of Texas will generate many advantages, mainly:

1. It will call for utilization of the capability from various sources to deal with the emergency, i.e. government, industry, academia, etc.

2. It will prevent needless duplication on the part of the industries and agencies in Texas.

3. It provides for a quicker response than normally would be provided by individual spiller responders or by the U. S. Coast Guard from locations outside of Texas.

4. It provides for an in-depth reservoir of management personnel.

5. It provides the focus for the planning and training activity.

6. It develops a consistency in the response.

7. It develops a mechanism to deal with spills from mystery sources and from those unwilling or unable to deal with spills.

Financial aspects of the Cooperative Plan are presented later.

It should be remembered that by establishing oil spill cooperatives for the State of Texas this does not in itself resolve all of our oil pollution problems. Indeed, no matter where you are dealing with a spill a hierarchy of resources depending on the size of the spill and duration of the cleanup is required. This hierarchy of resources ranges from the spillers own personnel, the resources of cooperatives, the resources of contractors, the resources of specific pollution control agencies, the military and other entities. Fig. 3 shows many of the resources available for the response hierarchy.

By developing a system of cooperatives for the Texas coastline we will have available immediately company resources and cooperative resources to be able to make a rapid response to a spill. We also have available the resources of those contractors in Texas and those that we can reach here in a reasonable period of time from Louisiana and other locations. We also have the Texas Department of Public Resources which is uniquely capable of dealing with oil on beaches and of ferrying men, equipment, and materials to and from barrier islands. By the combination of all these resources a substantial capability will be developed in the State of Texas.

This overall response group will be capable of making a

CAPABILITY

	Source	Oil Spill Cleanup									Technical Assistance/ Documentation					
		Organized Manpower	Oil Spill Equipment	Oil Spill Supplies	Construction Public Works Equipment	Vacuum Trucks & Tank Trucks	Vessels	Aircraft/ Helicopters	Manpower Logistics	Other	Oil Spill Specialists	Engineering Manpower	Scientific Manpower	Legal Manpower	Financial Management	Photo/ Documentation
INDUSTRY	Company Resources	x	x	x					x	x	x	x	x	x	x	x
	Cooperative Resources	x	x	x		x	x			x	x					
CONTRACTORS & SUPPLIERS	Oil Spill Contractors	x	x	x		x	x			x	x					
	Construction Contractors	x			x											
	Oil Industry Service Contr.	x			x	x	x	x	x							
	Oil Spill Suppliers		x	x												
CONSULTANTS & ACADEMIC ORGANIZATIONS	Oil Spill Consultants										x	x		x		
	Environmental Consultants												x			
	Universities										x					x
	Research Organizations										x	x	x			x
LOCAL/STATE GOVERNMENT	Public Works Transportation	x			x			x	x							
	Fire/Police	x														
	Port Authorities						x									
NATIONAL GOVERNMENT	Navy/Coast Guard	x	x				x	x	x		x					
	Army	x			x			x	x							
	Air Force	x						x	x							x
	Public Works	x			x				x							

Figure 3

ORGANIZATIONAL COMPONENTS OF THE RESPONSE HIERARCHY complete response on modest sized spills and the important initial response on a major catastrophic spill. This response would include sealing off the bays and estuaries under a pre-determined plan, making initial attempts at containing the oil offshore and/or carrying out initial containment and removal activities along the beachfront to prevent oil from spreading to other areas.

If we exceed these resources with a spill of catastrophic proportions that will require an extensive and costly cleanup, it is then possible to turn to resources such as traditional contractors, the military or other sources to replace the shared cooperative resources, or those of State agencies. The people involved from these entities could then return to their primary activities.

THE ROLE OF TEXAS
DEPARTMENT OF HIGHWAYS
AND PUBLIC TRANSPORTATION

The major role anticipated for the Texas Department of Highways and Public Transportation in the 1975 Texas Oil and Hazardous Materials Law has not evolved as envisioned. This agency was chosen for this role because it has some very unique capabilities which could play a very important role in oil spill response in the State of Texas. Three important areas are:

1. Fast, mechanized cleanup of impacted beaches.

2. Providing access to otherwise inaccessible areas in the coastal zone.

3. Operating the material handling components of the plan including stockpile of replenishment sand for the beaches and management of oil material reclamation and disposal areas.

The selection of the Department of Highways and Public Transportation for these roles was made with four major factors in mind, namely:

1. The availability of skilled engineering and management staff.

2. A large labor resource.

3. A large inventory of specialized public works equipment.

4. The agency role in operating the ferry system and the intercoastal waterway in the State of Texas.

For this agency to be a truly effective entity in dealing with the spill problem however, it must be authorized funds for this purpose, it must develop a cadre of trained people in the area, and it must acquire certain specialized equipment.

This major role for the Department of Highways and Public Transportation would be expected to continue as a part of the cooperative program outlined within this document. It would be expected that the district engineer or other staff engineers in each of the cooperative areas would participate actively in the conduct of the cooperative planning programs and the Texas Department of Highways and Public Transportation organization would provide men and equipment for many of the responses. Indeed, the state contribution to the cooperative organization might best be handled through the budget of the Department of Highways and Public Transportation rather than as a direct appropriation for the purpose.

The original selection of the Department of Highways and Public Transportation came as a result of recognizing that dealing with a major oil spill is a public works job of significant proportions requiring public works related management, logistics and equipment. In the State of Texas, only the Department of Highways and Public Transportation has the critical mass to provide an immediate work force to deal with such a task.

During the past year we have also learned that we must work very quickly to remove oil from our beaches or else the material is either buried, washed into our estuaries or deposited into our subtidal zone. Fig. 4 indicates this concept. We have also learned that equipment such as motor graders, front-end loaders, scraper loaders and vacuum trucks, if used quickly, can minimize the amount of sand removed from the beaches. It has however, been carefully drawn to our attention that sand removed by this process on many Texas beaches should be replaced either for legal or environmental considerations. This is because many of our barrier islands are suffering sand starvation as a result of many other environmental modifications made in Texas and elsewhere.

We strongly believe that this important State resource manned by fifteen thousand persons and with thousands of pieces of equipment can help make Texas a model state with regard to oil pollution control when this capability is combined with that of industry in the more traditional role of on-water containment and removal.

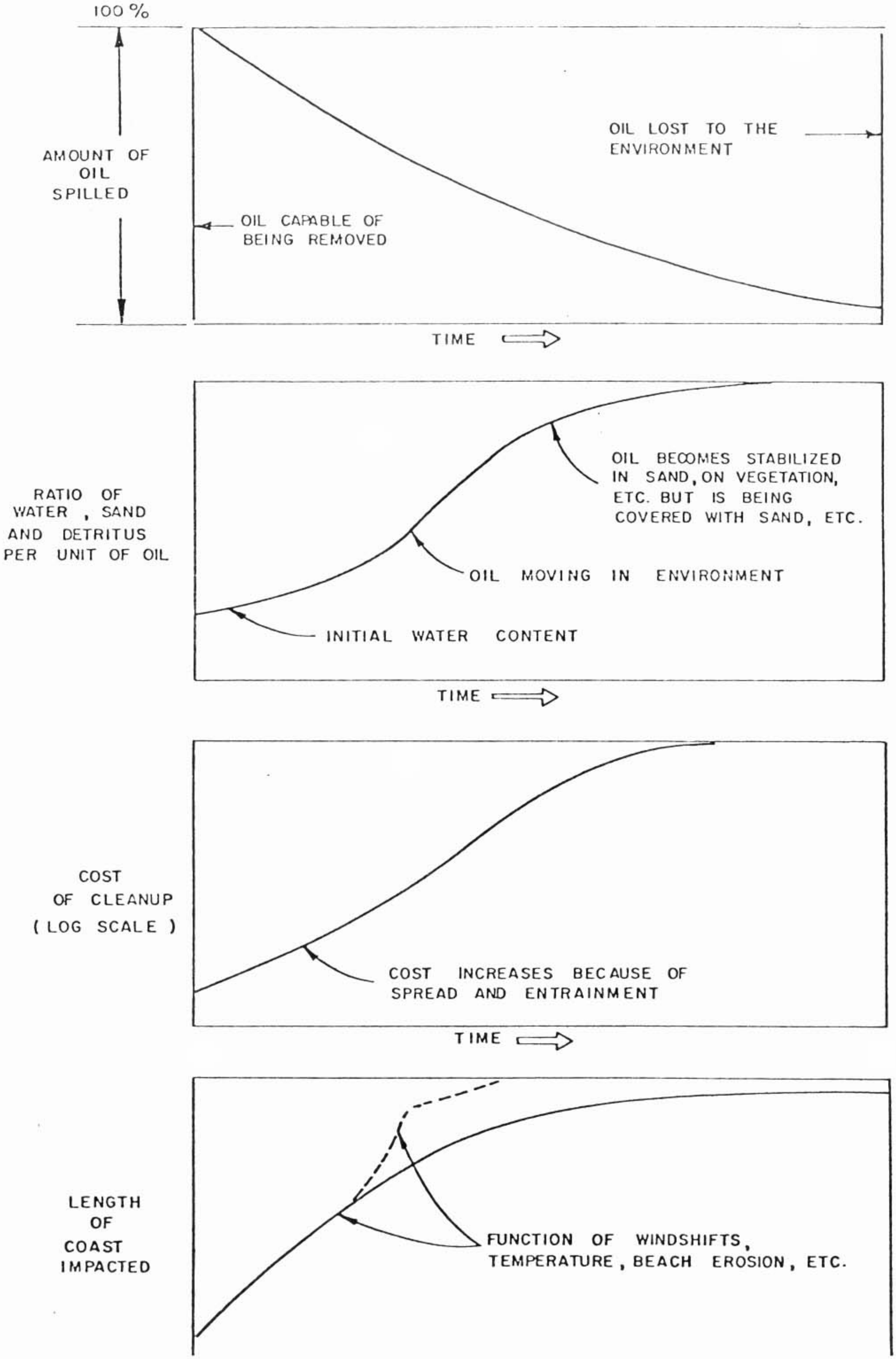
The use of the Texas Department of Highways and Public Transportation results in a substantial savings to the public in cleanup costs. These savings result because equipment used for most parts of the cleanup are normally used in other routine activities.

For an oil spill contractor to stockpile such routine public works equipment for only occassional use during spills would lead to substantially higher equipment charges. Similar savings result from using normal labor sources with effective Texas Department of Highways and Public Transportation supervision rather than higher priced short term labor and supervisors who would be hired for a cleanup and then laid off.

Funds accrued to the Texas Department of Highways and Public Transportation from cleanup fees would go to pay overtime charges and replacement labor to "catch up" on jobs delayed by participating in the response activity.

FIGURE 4

EFFECT OF DELAYED CLEANUP RESPONSE



Dr. Roy W. Hann, Jr.
December 1979

DESIGNATION OF A STRONG STATE RESPONSE TEAM

It would be expected that the State as a whole as well as each cooperative would establish a managerial response team. This would include specialists in a number of important areas such as:

1. Offshore response.
2. Coastal cleanup response.
3. Public information.
4. Accounting.
5. Communications
6. Documentation
7. Logistics
8. Oil Reclamation and Disposal, etc.

It would be expected that the local area team would handle any spill requiring only resources currently available within their area. On a spill which involved more than one area, or involved resources in addition to those needed for the local area, the State response team would be activated. The state response team would have similar components as well as specific Texas agency representation.

DESIGNATION OF A STRONG STATE TECHNICAL SUPPORT TEAM AND A STRONG STATE SCIENCE COORDINATOR

During the major spills of the last year, NOAA, through its hazardous material response program brought a large number of scientists to the State of Texas and carried out an aggressive program of providing science support to the cleanup activity and documenting the spill activities. However, these teams have generally only had modest input from local Texas scientists and indeed, many of those scientists in Texas who had some of the greatest knowledge dealing with petroleum and its effect on the marine environment have not been utilized. It is believed that a much more effective science support team for the State of Texas can be established from the agencies and academic institutions in the State of Texas. All that is necessary for initiating and carrying out such a program are the financial resources to activate and support such an activity. It is emphasized that this activity is not intended as the "observer" role provided at the spill scene by many State agencies. This is intended as a strong, active group to provide to the response team detailed scientific and engineering information including that collected in the impacted area. And to carefully document the physical, chemical and biological environments which are impacted. The reader is referred to the draft program entitled, Engineering and Scientific Studies Before, During and After a Spill, and to reports developed by the Texas A&M University Oil Spill Technical Assistance Team on the ESSO BAYWAY spill as a demonstration as to what is included in this type of program.

It is also emphasized that this is to be a free-standing State-supported science team with its own science support coordinator to interface both with State and/or federal On-Scene Commanders. Thus, the State will be represented one-on-one with the federal team rather than a subserviant role such as one of a large group of scientists brought in by the federal government.

ADVISORY GROUP
FROM GOVERNMENT,
INDUSTRY AND ACADEMIA

It is suggested that a group composed of government, industrial and academia personnel be organized in an advisory status to guide the state response activities, review past performances, and make recommendations for future capabilities. To some degree this team would serve the same role within the

State of Texas as the Federal Regional Response Team; however, the majority of the members of the advisory group will be selected because of their technical competence in the oil spill control field rather than as merely the formal representatives of the specific agencies.

LEGAL FRAMEWORK
FOR AN OIL SPILL PROGRAM

It is proposed that the Oil and Hazardous Material Control Law for the State of Texas be amended to accomplish the following:

1. To develop a State program to stimulate the development of, to participate in, and deposit cleanup resources with a series of oil spill cooperatives on the Texas coast.

2. To call for and finance effective site-specific oil spill contingency planning for the entire Texas coast and major river basins.

3. To provide funding to utilize existing information and to acquire adequate new scientific information on environmental resources and physical features to permit effective contingency planning.

4. To establish the mechanism and funding for a State oil spill technical and science support coordination program to utilize Texas engineering and scientific talent and existing data available at the time of major oil spills.

5. To establish an oil pollution advisory committee to act as a parallel to the federal regional response team and recommend policy determination, and decisions on products and methods for use in Texas.

6. To establish the mechanism for State-industry mutual assistance with appropriate means of compensating for these activities.

7. To establish a program of training activities developed to train personnel from management to equipment operators to

assure trained personnel are on hand to supervise and/or staff response efforts.

8. To establish liability on the part of the spiller for the repayment of spill cleanup costs and local administrative support costs charged directly to the State of Texas.

9. To provide the necessary regulations to permit the State supported cooperatives to take immediate action at the time of the spill in order to mitigate the damage of such spills to the State of Texas and to provide for repayment from the spiller and/or Federal Contingency Fund for such activities.

10. To expand the financial resources of the Texas Oil and Hazardous Material Fund to provide for response activities until repayment is received from the spiller and/or the Federal Contingency Fund.

11. To authorize the expenditure of State funds to provide access to remote barrier islands, boom anchorages, diversion areas, storage facilities, ferry landings and emergency ferries, etc.

12. To provide for the compensation by the spiller if known, by the State of Texas if unknown, to provide for third party damages to Texas citizens or property owners for proven economic losses incurred as a result of oil and hazardous material spills.

13. To authorize an agreement for the State of Texas to assume responsibility for response for all spills impacting the coastline or the rivers, bays and estuaries of Texas.

FINANCIAL ASPECTS
OF THE PLAN

It is expected that the industrial share of from one-half to two-thirds of the cost of the response program would be borne by those industries using the waterways for either internal or foreign commerce of oil and for oil production. This type of arrangement has worked quite well with cooperative organizations elsewhere in The United States. Sometimes the cost is shared on a unit basis, with each carrying an equal share, but more often it is based on some measure of the shipping volume or production which indicates the likelihood of risk.

Some mechanism needs to be established to insure that spills from ships will be responded to by the cooperatives. It would be expected that ships that were owned by the companies who are regular participants in the cooperative would automatically have provisions for calling on the capability of the cooperative organization. On the other hand, a problem exists with ships like the BURMAH AGATE, which are owned by oil companies or entrepreneurs who are not based in the Texas area. It may be possible for the ports to require a trip membership in the cooperative which would be secured before entering Texas coastal waters. The trip membership would authorize the cooperative to act instantaneously when a spill occurred and for a fee, to qualify them for the lower cooperative rental rates for the equipment and manpower.

As with all major cooperatives, a charge would be made by the cooperative for the actual response. This charge will include charges for personnel drawn from a variety of resources, a rental fee for the equipment which may be different for member or non-member users, and to repay the prorata cost for core staff. Traditionally, funds generated from such purposes are used to pay for actual expenses of the cleanup and that portion thereof which covers the cost for equipment rental or the salaries of the core staff is retained and used to offset the following year's budget.

A potential for federal funding for response equipment exists through either the Coastal Impact provisions of the energy program or windfall profits tax benefits. It could also be possible to arrange for the stationing of the U. S. Coast Guard, U. S. Navy or other equipment in the Texas area.

The cost of equipping and operating oil spill cooperatives differs markedly from place to place depending on the level of risk, the local economy and the level of environmental protection demanded by the citizens in the area.

The highly successful Clean Bay Cooperative in San Francisco Bay might compare with the larger proposed Texas Cooperatives. It has accumulated an inventory of $2.5 million in equipment during six years of life and has an annual budget of approximately $730,000. Of this, $220,000 is for everyday personnel and expenses, $275,000 for storage, equipment maintenance and repair, $85,000 for planning, training and studies and $100,000 capital acquisition.

The Southern California Offshore Cooperative has a budget on the order of a half million dollars per year.

Closer to home, the smaller Corpus Christi Area (SCA) has an annual budget of $143,500 per year.

All of these budgets are core budgets with additional funds being expended for direct response expenditures. Co-op costs are usually larger in the early equipment acquisition years.

It is anticipated that the overall cost to Texas of the Cooperative Program would be a sum of the following components:

1. The State share of the Cooperative budgets for example:
2. The cost of membership in Clean Gulf
3. State construction costs for ferry landings, etc., plus
4. State administrative, training and planning costs.

No specific estimates are suggested for the appropriate State cost but it is believed that the overall cost will be very small compared to the value of the oil industry to the State of Texas and the value of the tourist, fisheries and other marine resources of the State.

Oil spills in Texas from an ocean going tanker are likely covered by the TOVALOP or CRISTAL international insurance programs which would pay not only cleanup costs but also <u>reasonable</u> economic damage costs up to 75 million dollars. Thus, those in the tourist, fisheries, offshore supply and other industries and individual properties would be compensated for their damages.

The same would be true under both the Civil Liability Conventions and International Fund Convention if The United States had ratified these conventions. Unfortunately, they have not been ratified by The United States to date.

U. S. legislation normally parallels international programs. Our main oil pollution act was the Water Quality Act of 1970 which at that time followed the international programs by providing only for oil spill cleanup cost payment. Pending "Superfund" legislation which would amend the Water Quality Act includes third party damage provisions has been bogged down for various reasons; primarily by the inclusion of hazardous materials in the bill.

Thus Texas citizens are not covered for damages from U. S. Coastal Trade barges and ships not under the TOVALOP or CRISTAL nor from spills from foreign drillings, tankers in ballast, and freighters with oil as fuel.

It would be appropriate for Texas to consider the programs established in other states such as Maine which utilize the resources of a state pollution fund to pay legitimate damages incurred to citizens and businesses economically damaged by oil spills.

SUMMARY AND CONCLUSIONS

This document serves as a brief skeleton of a potential oil pollution control plan for the State of Texas which can provide for a much more effective defense against oil pollution than has been achieved during the past year. The achievement of the program components will let Texas better control the quality of its coastal resources and assure its citizens that government and industry can work together to minimize the impact of the occasional instance of oil pollution associated with the Petroleum activities that are so important to the State of Texas.

There have been many different successful formats for oil pollution response in different areas of the world. The ideas collected together in this document appear to be a workable selection of known and accepted components which have worked elsewhere and which appear well suited for working in Texas. Any other selection of components which will work effectively are equally acceptable. What is important is that efforts be initiated to develop an effective defense for oil pollution in Texas.

APPENDIX B

Use of a Mixture of Beach Sand and Inspissated Oil
Dune Nourishment and Stabilization
THE BUREAU OF ECONOMIC GEOLOGY
W. L. Fisher, Director

Observations made on South Padre Island in October 1979 revealed that much of the oil on the beach and at the toe of fore-island lanes had lost most of its volatiles and that the inspissated oil (that is, oil from which volatiles escaped) had been broken down into sandsize particles. At the time the observations were made the wind was strong and from the south-southeast; virtually none of the sand and associated sandsize hydrocarbons were being moved by the wind.

Inspissated hydrocarbons are not detrimental to the beach-dune environment since they are relatively inert. Sand-sized tar-like particles, if in sufficient quantity, serve as "sediment binders" or as a weak cementing agent. The Texas Highway Department has, in the past, sodded certain road cuts, and in order to stabilize the cover; the THD seeds and sprays the sod with an oilbase emulsion. Certain Arab nations are currently converting areas of migrating sand dunes into productive agricultural lands, first by stabilizing the dunes with crude oil, and secondly by seeding the dunes with various grasses, shrubs, and trees. It has thus been demonstrated that dunes can be stabilized by using hydrocarbons as a weak cementing agent, and that these hydrocarbons are not detrimental to subsequent vegetation growth.

As an example along the Texas barriers during the winter of 1974, fore-island dunes and an adjacent dune ridge were excavated to elevations near sea level to facilitate laying a pipeline across Mustang Island. After the pipeline was buried, the dunes and dune ridge were restored to their original contour. The barren sand was sprayed with an oil-based emulsion, sprigged with new vegetation, and covered with burlap to provide temporary stability. During the following spring, the restored dunes were colonized by certain types of vegetation such as sunflowers that typically occupy disturbed sand areas. In subsequent months, these primary flora gave way to natural dune vegetation. The revegetation process has proceeded to the extent that the area is essentially as it was prior to excavation.

Even trained observers with site-specific information have difficulty in detecting where the pipeline transects the dunes.

The south Texas barrier islands are in a semi-arid region where the prevailing southeast winds and hurricane storm surge inflict considerable erosional damage to the islands, particularly to the fore-island dunes. Since this is an area of low rainfall, vegetation on the fore-island dunes is sparse in many areas. Fore-island dunes werve to absorb much of the force impacted on the island by hurricanes. Fore-island dunes retard beach erosion during storms, and serve as a dam to hurricane storm surge flooding. Where fore-island dunes are low, or absent, storm damage may be severe.

In the past there have been some attempts to create and stabilize fore-island dunes to South Padre Island.[1] Picket fences were used to form a physical barrier to wind-transported sand, and native salt-tolerant grasses were then used to stablize these incipient dunes. Research on the stabilization of fore-island dunes has shown that bitter panicum and sea oats are the best plants for dune stabilization. It was also discovered that transplants of these grasses was much more successful than planting seed. The best time for transplanting sea oats is December through February and October through May for bitter panicum. Irrigation is required when vegetating barren dunes; also required is some sort of sediment binder, for example, burlap or an open-weave netting; in this case, inspissated hydrocarbons would serve as the sediment binder. Optimum spacing of transplants was approximately 70 cm; minimum dune height (in order to alleviate the adverse effect of hypersaline interstitial water) at which stabilization with grasses will be successful is about one meter.

The sand and hydrocarbons that are scraped off the beaches could be used advantageously to stablize existing fore-island dunes, and to initiate fore-island dunes in certain hurricane washover areas. It is recommended that these "experimental dunes" be not less than one meter in height, and that they be horizontally continuous for a few

[1]Dahl, B.E., Fall, B.A., Lohse, A., and Appan, S.G., 1974, Stabilization and Reconstruction of Texas Coastal Foredunes with Vegetation: Final Report to U.S. Army Corps of Engineers, Coastal Research Center, Fort Belvoir, V., Gulf Universities Research Corsortium, GURC Report, No. 139, 324 P.

hundred feet. They should consist of an appropriate mixture of oil or tar and sand. A picket fence should be erected immediately seaward of these experimental dunes as a protective measure against wind erosion. It is recommended that a general all-purpose fertilizer be applied at the time of seeding or transplanting. To further enhance rapid establishment of a vegetation cover, it is recommended that the experimental dunes be frequently irrigated. Utilization of the sand and hydrocarbons, removed from the beach during cleanup operations, to stabilize existing fore-island dunes and to initiate new fore-island dunes would not remove sand from the buffer zone, and therefore would not further deplete the sand budget; further depletion of the sand budget would aggravate shoreline erosion, which is high on certain stretches of the south Texas barriers. Information is available to define specific beach zones of erosion accretion, or equilibrium.

Advantages of using the sand and hydrocarbons for dune stabilization are several. First, the cost of transporting the sand and hydrocarbons to fore-island dune areas would be considerably less than hauling the materials to some back-island area. Secondly the sand budget would not be further depleted in an area that is already in an erosional state. Thirdly, the stabilization of existing fore-island dunes and/or establishment of new fore-island dunes would serve to enhance the natural stability of the vegetated coastal barrier dunes and provide further critical protection for hurrican storm surges.

APPENDIX C

December 20, 1979

Ms. Nevenna Travis
Texas Systems of Natural Laboratories, Inc.
610 Brazos Street
Austin, Texas 78701

Dear Ms. Travis:

On December 19, you inquired about the Department's computer models of the bays and estuaries. I understand you are interested in whether or not these computer models can be used to predict movement of oil within the Texas estuarine system. We feel that with additional information, which would have to be obtained at the seaward location of the Gulf and estuarine exchange points, the computer model could be used to predict the movement of oil and "tar balls" within the estuaries that enter through these inlets. The data that are needed are samples of the concentrations of materials passing from the Gulf through tidal action into the estuary.

The Department's two-dimensional tidal hydrodynamic model computes the tidally generated flows and velocities in the two horizontal coordinate directions given certain simplifying assumptions. The most important assumption is that the bay is well-mixed in the vertical, i.e., the velocity and density are constant with depth. In addition, in order to solve the differential equations which describe the tidal motion in a well-mixed estuary, the estuary is represented by a matrix of one-nautical mile square computational cells. The equations are solved for each of these computational cells, thus, the computed velocities in each of the two coordinate directions represent an average velocity across a one-nautical mile front.

To simulate real-time variations in tidal velocities, the tidal hydrodynamic model can be modified to output "instantaneous" velocities at time intervals as short as two minutes, subject to the availability of sufficient computer storage.

The operation of the tidal hydrodynamic model requires the specification of certain input conditions. These input conditions which must be known include the tidal conditions at all tidally influenced boundaries of the estuary, i.e., the Gulf exchange pass and all side bays, all freshwater inflows, wind speed and direction, evaporation, and rainfall. Thus, the long-term simulation of tidal velocities requires the specification of the Gulf tidal conditions throughout the simulation period or the assumption that the Gulf tidal conditions remain constant from one tidal cycle to the next.

The use of these computed tidal velocities to predict the dispersion of a pollutant throughout the estuary requires, in addition to the assumption of a vertically well-mixed estuary, that the pollutant be a "conservative" constituent. This means that there is no significant, short-term (i.e., daily) degradation or generation of the pollutant within the estuary by physical, chemical, or biological reactions.

Subject to these assumptions, the instantaneous velocities can be used to predict the movement of the pollutant within the estuary over a short time period such as a tidal cycle, or the tidal velocities, averaged over a tidal cycle, can be used in conjunction with the conservative mass transport model to predict the "gross" movement of the pollutant over long-time periods, assuming a continuous repetition of tidal conditions from one tidal cycle to the next.

The models described above have been developed for the purpose of analyzing the freshwater inflow needs of the bays and estuaries of Texas. Each model has been computed and calibrated using "field" data collected in each respective estuary. In our judgment these individually constructed computer models are the best available tool with which to make estimates of the transport of suspended material that might enter the bays. However, I reiterate, it would be necessary to sample at the tidal inlets, in order to collect data about the concentration of materials in suspension.

We will be happy to provide descriptive detail of the models and to provide further explanations.

Sincerely,

Herbert W. Grubb

Herbert W. Grubb
Director, Planning and
Development Division

Input-Output Branch
List of Reports

"Main Models"

TITLE	AUTHOR(s)	NUMBER
The Input-Output Model for the State of Texas	Grubb Lesso	5102-R25-0973-RAN
A Structural Analysis of the Texas Economy Using Input-Output Models	Grubb	7400-R14-0673
Using Input-Output Models for Economic Analyses of Energy Consumption in Texas	Grubb	0025-030-1174-NR
Selected National Economic and Energy Policy Impacts on the Texas Economy: An Input-Output Simulation Model Analysis	Grubb Holloway Grossman	0025-051-0675-NR
An Economic Simulation Model for Analysing Energy Policy Impacts in Texas	Holloway Grubb Grossman	0025-052-0775-NR
Water Resources Planning: Analytic Techniques and Policy Implications from a State Viewpoint	Grubb Holloway Williams	0025-054-0875

TWODB SOFTWARE INVENTORY PROGRAMS RECEIVED
AS OF OCTOBER 3, 1979

PEP	Parameter Estimation Program	Quentin Martin
PIPEX-I	Pipeline Optimal Capacity Expansion Model	" "
CAPEX-I	Pump Station Capacity Expansion Model	" "
DEMAND-II	Irrigation, Industrial & Municipal Water Demand Model	" "
SIM-IV	Multibasin Simulation & Optimization Model	" "
DPSIM-I	Opt. Cap. Expan. Model for Surface Water Systems	" "
AL-IV	Water Supply Allocation Model	" "
SIMYLD-II	River Basin Simulation Model	" "
CANAL-I	Water Conveyance Canal Design Model	" "
ECOSYM	Economic Simulation Model	" "
QUAL-I	Stream Quality Model	Mike Sullivan
QUAL-II	Stream Quality Model	" "
LAKECO	Lake Ecological Model	" "
QNET-I	Multibasin Water Quality Simulation Model	" "
DOSAG-I	Stream Quality Routing Model	" "
DELTA	Delta, River Delta Hydroynamic and Water Quality Simulation Model	" "
FILLIN-I	Multi-Site Data Fill-In	Steve Densmore
SEQUEN-I	Sequence Analysis Program	" "
RESOP-II	Reservoir Operating & Quality Routing Pgm	Lew Browder
IMAGEW-I	Well Field Drawdown Model	Tommy Knowles
CARIZO	Carrizo Aquifer Digital Model	" "
GWSIM-II	Ground Water Simulation Program II	" "
GWSIM	Groundwater Simulation Program	" "
ESTECO	Estuarine Ecologic Model	Gordon Thorn
DEM	Dynamic Estuary Model	" "
HYD	Tidal Hydrodynamic Model	" "
RIVTID	River/Tidal Hydrodynamic Model	" "
SAL	Salinity Transport Model	" "
AUTO QD	Auto Qual Modeling System	Dale White
GBP	Galveston Bay Project Nitrogenous BOD Model	" "
GBP	" " " Hydraulic Model	" "
QUAL-IIQ	Qual-IIQ	" "
AUTOSS	Auto-Qual Modeling System	" "
GBP	Galveston Bay Salinity Model	" "
GBP	Galveston Bay Project BOD Model	" "
GBP	Galveston Bay Project DO Model	" "

WD0900	Flood Hydrograph Analysis	T. R. Evans
WD9000	BURDAT	" " "
WD1100	Water Surface Profiles	" " "
WD1200	Unsteady Flow Model (SOCH/GEDA)	" " "
WD1300	Reservoir Operating & Quality Routing	" " "
WD1400	Flood Flow Frequency Analysis	" " "
WD2000	Flood Hydrograph System	" " "
WD2900	Irrigation Water Requirements	" " "
WD4500	Hymo	" " "
WD5300	STORM	" " "
WD5900	River Tidal Hydrodynamics & Quality	" " "
WD6200	LOQUOT	" " "
WD7200	Inter-Industry Resource Model	" " "
WD8500	High Plains Input-Output Model	" " "
DW1600	Moving Average	" " "
PRCSYS	Pecos River Compact System	Larry Crow
WAPAM	Water Availability & Priority Allocation	" "

TWODB SOFTWARE INVENTORY PROGRAMS
continued

AL-IV	Water Supply Allocation Model	T. R. Evans
AQCHEM	Aquifer Chemical Quality	" " "
ASTEP	ASTEP	" " "
AUTO QD	AUTO - Qual Modeling System	" " "
AUTOSS	AUTO - QUAL Modeling System	" " "
BMD	BMDP Biomedical Computer Programs	" " "
CALFORM	Computer Mapping System	" " "
CAPEX-I	Pump Station Capacity Expansion Model	" " "
CARIZO	Carrizo Aquifer Digital Model	" " "
CHEMQ	Chemical Quality	" " "
CPS-1	Contour Plotting	" " "
DAM	DAM	" " "
DEM	Dynamic Estuary Model	" " "
DEMAND-II	Irrig., Ind. and Mun. Water Demand Model	" " "
DES	Dynamic Economic Simulation Model	" " "
DISSPLA	Computer Graphics	" " "
DMED	Streamflow/Precip Graphics Routine	" " "
DMS 1100	Data Base Management System	" " "
DOSAG-I	Stream Quality Routing Model	" " "
DPSIM-I	Opt. Cap. Expan. Model for Surf. Water Sys.	" " "
EOCSYM	Economic Simulation Model	" " "
ELLTAB	EBLTAB	" " "
ESTECO	Estuarine Ecologic Model	" " "
ESTPOL 1	ESTPOL - I	" " "
ESTPOL 2	ESTPOL - II	" " "
FASTEP	Step-Drawn Test Analysis by Computer	" " "
FILLIN-I	Multi-Site Data Fill-In	" " "
GBP	Galveston Bay Project BOD Model	" " "
GBP	Galveston Bay Project DO Model	" " "
GBP	Galveston Bay Project Hydraulic Model	" " "
GBP	Galveston Bay Project Nitrogenous BOD Model	" " "
GBP	Galveston Bay Salinity Model	" " "
GWSIM	Goundwater Simulation Program	" " "
HAREQ	Harrill's Equation	" " "
HCM	Hirsch Cloud Model	" " "
HYD	Tidal Hydrodynamic Model	" " "
IMAGEW-I	Well Field Drawdown Model	" " "
IMSL	International Mathemathical and Statistical Libraries	" " "
LAKECO	Lake Ecological Model	" " "
LARSYS	LARSYS	" " "
MATH/STAT	PACK MATH/STAT PACK	" " "
MOSS-IV	Monthly Streamflow Simulation	" " "
O'Connor	Program GALV Hydroscience Model for the Houston Ship Channel	" " "

PEP	Parameter Estimation Program	T. R. Evans
PIPEX-I	Pipeline Optimal Cap. Expansion Model	" " "
POLYVRT	POLYVRT	" " "
PRCSYS	Pecos River Compact System	" " "
QNET-I	Multibasin Water Quality Sim. Model	" " "
QUAL-I	Stream Quality Model	" " "
QUAL-II	Stream Quality Model	" " "
QUAL-IIQ	QUAL-IIQ	" " "
RESOP-I	Reservoir Operation & Quality Routing Program	" " "
RIVER	Program RIVER by Hydroscience, Inc.	" " "
RIVTID	River/Tidal Hydrodynamic Model	" " "
SAL	Salinity Transport Model	" " "
SEISMIC	Refraction Seismic Program	" " "
SEQUEN-I	Sequence Analysis Program	" " "
SIM-IV	Multibasin Sim. & Optimization Model	" " "
SIMYLD-II	River Basin Simulation Model	" " "
SPSS	Statistical Package	" " "
SYMAP	Computer Mapping System	" " "
SYMVU	3-D Plotting System	" " "
SYSTEM 2000	Data Base Management System	" " "
WAPAM	Water Availability & Priority Allocation Model	" " "
WQAL	Water Quality	" " "
WRECEV	WRECEV	" " "
ZOHDY-S	ZOHDY-SCLUMBERGER	" " "

APPENDIX D

DRAFT

PRELIMINARY OUTLINE FOR OFFSHORE

ECOLOGICAL DAMAGE ASSESEMENT STUDIES

Studies Relative to the Fate of Spilled Oil on the State Submerged Lands, Utilizing Baseline Data Collected from 1975 through 1977 for Coastal Zone Management

Submitted by:

Bureau of Economic Geology

The University of Texas at Austin

In cooperation with:

The U. S. Geological Survey and

University of Texas Marine Science Institute,

Port Aransas Marine Laboratory

Contact: E.G. Wermund, Assoc. Dir.
Bureau of Economic Geology
The University of Texas
Box X, University Station
Austin, Texas 78712
(512) 471-1534

Preliminary Proposal for

DAMAGE ASSESSMENT OF THE 1979 GULF OF MEXICO OIL SPILL

Introduction

The purpose of this proposed work is to assess any damage of the 1979 Gulf of Mexico Oil Spill impacting State Submerged Lands. State Submerged Lands include all estuarine and bay lands as well as the Gulf of Mexico shelf from the beach to three leagues (approximately 11 miles). This preliminary proposal supplements that submitted by the U. S. Geological Survey and Texas Marine Science Institute.

The Baseline

An extensive program of sampling State Waters was included in the Texas Coastal Zone Management Program when directed by the General Land Office of Texas. Therefore a data base, valuable for damage assessment from any adverse impact, has already been collected for State Submerged Lands as reported by McGowen and Morton (1979). The data base collected in 1975-1977 includes clamshell samples from the submarine bottom on one mile centers (nearly 6700 samples in all). These samples were and are being studied for sediment type, textural analyses, multielement (30) geochemical analyses, and biological analyses. Biological analyses include identification of all molluscs, crustaceans, and worms; marine flora as well as foraminifers in Laguna Madre are under separate study. Live and dead organisms are studied in all cases. In addition, geophysical data support the bottom sampling.

Completed studies include: sediment types for the entire area; textural analyses of all but Port Lavaca, Port O'Connor and the Beaumont-Port Arthur sheets; biological analyses of the Corpus Christi (100%) and Houston-Galveston (85%) sheets; geochemical analyses of the bays; and geophysical analyses of the shelf. Damage assessment will require the supplementation of completed analyses with further analyses of the samples from the data base that are not yet analyzed.

Damage Assessment

Most damage to State Submerged Lands will be observed in the benthic biologic population. These damages may include direct short-term effects such as the rapid destruction of bottom dwelling organisms from contact with toxic hydrocarbons. Another order of damage may relate to long-term toxicity of residues, either imparing organisms or preventing the reoccupation of normal ecologic niches. A part of this toxicity can be derived from inorganic components of the spill residua identified as trace elements. The bottom dwelling population in the data base indicates the health of a vital food chain which impacts both commercial and sport fishing. Whereas the damage to tourism may be short term, the damage to food gathering on the Texas coast might have long-term impacts.

The advantage of a recent data base already under study leads to a quantitative assessment of the effects of the spill. Ratios of living to dead organisms before and after the spill can be assessed. The quantitative data can be estimated in dollars, especially for commercial molluscs (oysters) and cretaceans (shrimp and crabs).

Quantitative data also contribute to planning for the longevity of damages. For example, a rate of recovery of organisms returning to normal sites can be used to predict how much commercial (and sport) fishing may be appropriate in the future. An analogy is overgrazing and planned pasture control for cattle and sheep.

These same quantitative data, collected for Coastal Zone Management, have many applications in addition to assessing oil spill damage. These data impact (1) pipeline construction for collection and distribution of oil and gas, (2) dredging for coastwise as well as potential deep port channels, (3) disposal of spoil, (4) monitoring of marshes, (5) beach engineering, and others. From the same data base, effects of natural catastrophes such as hurricanes can also be monitored for economic impacts on natural systems.

The Texas Coastal Zone Management program was implemented through the General Land Office of Texas from 1975-1978. Policy guidance was provided by the Interagency Council for Natural Resources (ICNRE), whose composition is shown in Table 1. A successor interagency group named the Natural Resources Council became the policy group by statute in 1977. In late 1978, the Governor of Texas reassigned all responsibility for the Coastal Zone Management Program to the Natural Resources Council. The 1979 legislature has reformulated that body into a group named the Texas Energy and Natural Resources Advisory Council (TENRAC), effective September 1, 1979. The TENRAC members are dominated by natural resource agencies of the old ICNRE, and the council is co-chaired by the Governor and Lieutenant Governor.

Identification of Studies and Users

1. Name of Study

Integrated studies of the fate of hydrocarbons relative to sediment transport, benthic infaunal communities and trace chemistry of the upper benthic sediment column, Texas Submerged Lands.

* Users: (1) State and Federal agencies, municipalities, and other local governmental units, especially those having mandated regulatory responsibilities and those supplying public services likely to be impacted, such as parks and recreational facilities; (2) shrimp and fishing industries; (3) tourist and recreational industries; (4) oil and gas industries; (5) international bodies concerned with laws of the sea; (6) concerned members of the public; (7) civic groups; and (8) congressional oversight committees and judicial authorities concerned with damage assessment.

2. Where

Offshore to three leagues and in the bay-estuarine systems in both short and long-term context for direct comparison to baseline data and to establish a predictive timeframe for the ultimate fate and effect of oil released in a major spill that becomes regionally distributed. The work should be coordinated closely with similar studies to be done in the surf zone and on the adjacent beach sectors. The need for such coordination is especially emphasized.

3. When

To begin soon after shutdown of flow from the IXTOC-1 well has been completed. Tentatively an initial cruise should be scheduled for mid-November, occupying, for sampling purposes, stations along Bureau of Economic Geology transects which best complete baseline study. Each of these transects gave what might be called subprovince characterizations that would be expected to give good indications of stress from any pollution by the oil. A follow-up cruise would be made in March 1980, and again some time in the period May to September, depending on information gathered in the two earlier cruises. Continuation and frequency of cruises in years 2 and possibly 3 would depend on evaluation of the results as the study progresses.

Study Outline

The study would include reoccupation of the sites reported by McGowen and Morton (1979) in the same time frame reported in the U. S. Geological Survey Proposal. The benthic sediments would be sampled for relating post-spill conditions to the baseline data to determine the degree to which oil eventually becomes incorporated into the sediments and to determine the ultimate influence of oil in sediments and biota. The shelf sediments out to three leagues would be sampled by the team collecting the U. S. Geological Survey samples. The Bureau of Economic Geology would sample the bays along the same (or appropriate) transects.

The samples would then be analyzed in laboratories for textural, inorganic geochemical, and biological properties.

Budget

An estimated budget from which to pursue the monitoring of the impact of the 1979 Summer Oil Spill on the Texas Coast is shown in Table 2. Shown are high and low figures if one or three bays are studied along with the four passes. Shelf sample spacing is 50 lines (the BLM number) at two (2) mile intervals for the Low estimate; spacing is 100 lines at two (2) mile intervals or 50 lines at one (1) mile intervals for the High estimate plus denser sampling near the passes. Basic biologic descriptions require about four (4) man days per sample; whereas, the descriptions of later samples taken during four (4) seasons for two (2) years take one (1) man day. It is possible to expand or compress the program with these basic assumptions. You should also be aware that The University indirect costs are included in this budget.

The Bureau of Economic Geology will contribute more than 10 percent of the project costs. These costs include administration, textural analyses and one-third the geochemical analyses. The latter analytical costs are based on costs per sample established by two years of analyses.

Reference

McGowen, J.H. and Morton, R.A., 1979, Submerged Lands of Texas, sediment distribution, bathymetry, faults and salt diapirs; The Univ. Texas, Bur. Econ. Geol., Special Report, 47 p., 7 maps.

Table 1. Interagency Council for Natural Resources and Environment.

Department of Agriculture	
Air Control Board	
Bureau of Economic Geology	
Forestry Department	
General Land Office	
* Department of Health Resources	
* Department of Highways	
Historical Commission	
Departments of Parks and Wildlife	
Railroad Commission	
Department of Soil Conservation	
* Water Development Board	Water Resources
* Department of Water Quality	Water Resources
* Department of Water Rights	Water Resources

* By legislative statute some names are modified and the water agencies combined.

TABLE 2

ESTIMATED BUDGET TO MEASURE IMPACT OF

1979 SUMMER OIL SPILL ON TEXAS SUBMERGED LANDS

		HIGH	LOW
1.	SHELF BIOLOGY	$326,984	$171,012
	Base description	$653,964	$342,024
	8 Seasons description		
2.	SHELF SEDIMENTOLOGY	$ 6,250	$ 2,500
	8 trips =	$ 50,000	$ 20,000
3.	SHELF GEOCHEMISTRY/trip		
	Inorganic (30 trace elements)	$ 19,200	$ 10,200
	8 trips =	$153,640	$ 86,600
4.	BAY SAMPLING/bay/trip	140 samples	80 samples
	Air Boat Rental	$3,000	$1,750
	People	$1,250	750
		$4,250	$2,500
	8 trips =	$34,000	$20,000
	3 bays =	$102,000	$60,000
5.	BAY BIOLOGY/per bay		
	Base description	$70,427	$40,244
	8 Seasonal descriptions	$140,848	$80,488
		$211,281	$120,732
	3 bays =	$633,843	$362,196
6.	BAY BEOCHEMISTRY/bay/trip		
	Inorganic (30 trace elements)	$4,200	$2,400
	8 trips =	$33,600	$19,200
	3 bays =	$100,800	$57,600
7.	BAY SEDIMENTOLOGY	$6,250	$2,500
	8 trips =	$50,000	$20,000
8.	TRAVEL/per trip	$8,000	$4,000
	8 trips =	$64,000	$32,000
9.	EXPENDABLES/per yr.	$10,000	$5,000
10.	EQUIPMENT/one cost	$120,000	$70,000

DRAFT

PRELIMINARY OUTLINE FOR OFFSHORE ECOLOGICAL DAMAGE ASSESSMENT STUDIES

Offshore Studies Relative to the Fate of Spilled Oil in the Nepheloid Layer and Bottom Sediments, Utilizing Baseline Data Collected from 1974 through 1977 on the South Texas OCS

Submitted by:

The U. S. Geological Survey

In conjunction with:

University of Texas Marine Science Institute,

Port Aransas Marine Laboratory

Contact: Henry L. Berryhill, Jr.
U. S. Geological Survey
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FTS 734-3294

INTRODUCTION

From 1974 through 1977, the U. S. Geological Survey through the field office in Corpus Christi, Texas, participated in a regional baseline study of the South Texas OCS, the region that has received the initial impact of the IXTOC-1 oil in U. S. waters. The general work plan outlined herein is presented with the understanding that the U. S. Geological Survey group in Corpus Christi will join investigators from the University of Texas Marine Science Laboratory at Port Aransas as a scientific team in carrying out integrated studies. These studies also should be integrated with those of the Texas Bureau of Economic Geology and likely with Texas A&M University as well.

The Baseline

Personnel from the U. S. Geological Survey group at Corpus Christi, as participants in the 4 years of baseline environmental studies on the STOCS sponsored by the Bureau of Land Management, collected samples from 264 stations spread regionally over the STOCS for a variety of geological and geochemical studies: sediment texture of benthic sediments, amounts of infaunal bioturbation over the region as an aspect of regional sedimentation; chemical analyses to measure rates of sedimentation; trace metals chemistry of benthic sediments, radiography of benthic sediments; and the texture, chemistry and amounts of suspended matter in the water column synoptically on a seasonal basis with emphasis on the nepheloid layer. In addition and as a part of the biological and hydrocarbon chemistry studies being made by UT, Port Aransas, the U. S. Geological Survey did the textural analysis and trace metals chemistry for all samples collected seasonally, and in some cases monthly, by UT along the master monitoring transects used for the baseline studies. All of these data are available in reports prepared for each year of study and are summarized along with related aspects of data in a series of Atlas Maps. The work recommended would closely utilize the baseline information available. As part of the studies sponsored by the Bureau of Land Management, Texas A&M University concentrated on the string of reefs on the outer shelf and the surrounding nepheloid layer. Personnel from USGS participated in some of those cruises. The USGS and the Bureau of Economic Geology cooperated in collection of data in State waters.

Identification of Studies and Users

1. Name of Study

Integrated studies of the fate of hydrocarbons relative to sediment transport, benthic infaunal communities and trace chemistry of the water and upper benthic sediment column, South Texas offshore.

* Users: (1) State and Federal agencies, municipalities, and other local governmental units, especially those having mandated regulatory responsibilities and those supplying public services likely to be impacted, such as parks and recreational facilities; (2) shrimp and fishing industries; (3) tourist and recreational industries; (4) oil and gas

industries; (5) international bodies concerned with laws of the sea; (6) concerned members of the public; (7) civic groups; and (8) congressional oversight committees and judicial authorities concerned with damage assessment.

2. Where

Offshore in both short and long-term context for direct comparison to baseline data and to establish a predictive timeframe for the ultimate fate and effect of oil released in a major spill that becomes regionally distributed. The work should be coordinated closely with similar studies to be done in the surf zone and on the adjacent beach sectors. The need for such coordination is especially emphasized.

3. When

To begin soon after shutdown of flow from the IXTOC-1 well has been completed. Tentatively an initial cruise should be scheduled for mid-November, occupying, for sampling purposes, stations along transects II and III of the STOC baseline study. Each of these transects gave what might be called subprovince characterizations that would be expected to give good indications of stress from any pollution by the oil. A follow-up cruise would be made in March 1980, and again some time in the period May to September, depending on information gathered in the two earlier cruises. Continuation and frequency of cruises in years 2 and possibly 3 would depend on evaluation of the results as the study progresses.

Study Outline

The components of study would include a release of sea drifters, surface and bottom, from a light aircraft to confirm the water circulation data used for the baseline centroid projections shown in Berryhill and others, 1976, and to document the change in flow regime to the south after October when oil in the water should begin moving southward.

The nepheloid layer would be sampled and analyzed both chemically and texturally. The rationale for studies on the nepheloid layer and the upper sediment column is that all hydrocarbons that do not evaporate become either adhered to clay minerals and organic particles or coagulate. In both cases, the hydrocarbons end up at the surface of the seafloor from where the infauna works it into the upper sediments. The infauna is highly critical in the food chain as it relates to species of commercial interest and consequently the endangered species. Comparison of the infauna activity in polluted sediment with the baseline data will provide direct answers to the "users" about the long-term impact of this IXTOC-1 oil spill. USGS would make both texture and trace metals determinations of the inorganic constituents in the nepheloid layer. As a part of the study, the water column would be sampled at mid-depth and near surface as a part of defining the extent, and thickness and chemistry of the nepheloid zone relative to the general water column. The special characteristics of the nepheloid layer may delay the transfer of hydrocarbons to the benthic sediments because of the affinity of the clay minerals in the layer.

The benthic sediments would be sampled for relating post-spill conditions to the baseline data to determine the degree to which oil eventually becomes incorporated into the sediments and to determine the ultimate fate of the oil in the sediments. The relation of oil to the sediments would emphasize the role of the infauna in working the oil into the sediments whence it enters the food chain; otherwise, studies would include the same studies made for the baseline.

Sampling would begin with reoccupation of stations along transects II and III and would be extended to other baseline stations as needed to provide sufficient coverage, and as indicated by results as the study progresses. After sampling at each station, skimming trawls would be made over the sample site and outward some one-fourth mile to determine the degree of tar ball concentration.

* The integrated summary and atlas (Berryhill and others, 1976) contains a very accurate prediction of the path and landfall of the oil along the Texas coast.

General Budget Request (yearly)

-- Operational expenses and salaries of support personnel	$ 60,000
-- Ship time	$ 30,000
	$ 90,000
Bureau overhead	$ 10,000
(Cost of a 3-year effort would be ∿ $300,000)	$100,000

Contribution to the study by USGS (yearly)

-- Professional Salaries	$ 30,000
-- Use of laboratories and equipment	18,000
-- General supplies, services and overhead support by USGS	12,000
-- Salary support by persons not covered by requested budget	22,000
Total	$ 82,000

The general plan presented is considered part of a team effort to include the University of Texas (both the Bureau of Economic Geology and the Marine Science Laboratory at Port Aransas) and possibly Texas A&M University. Furthermore, it is assumed that it will be closely coordinated with both the beach profile work and the work in the surf zone. Work along traverses involving the three groups should be considered a total team effort.

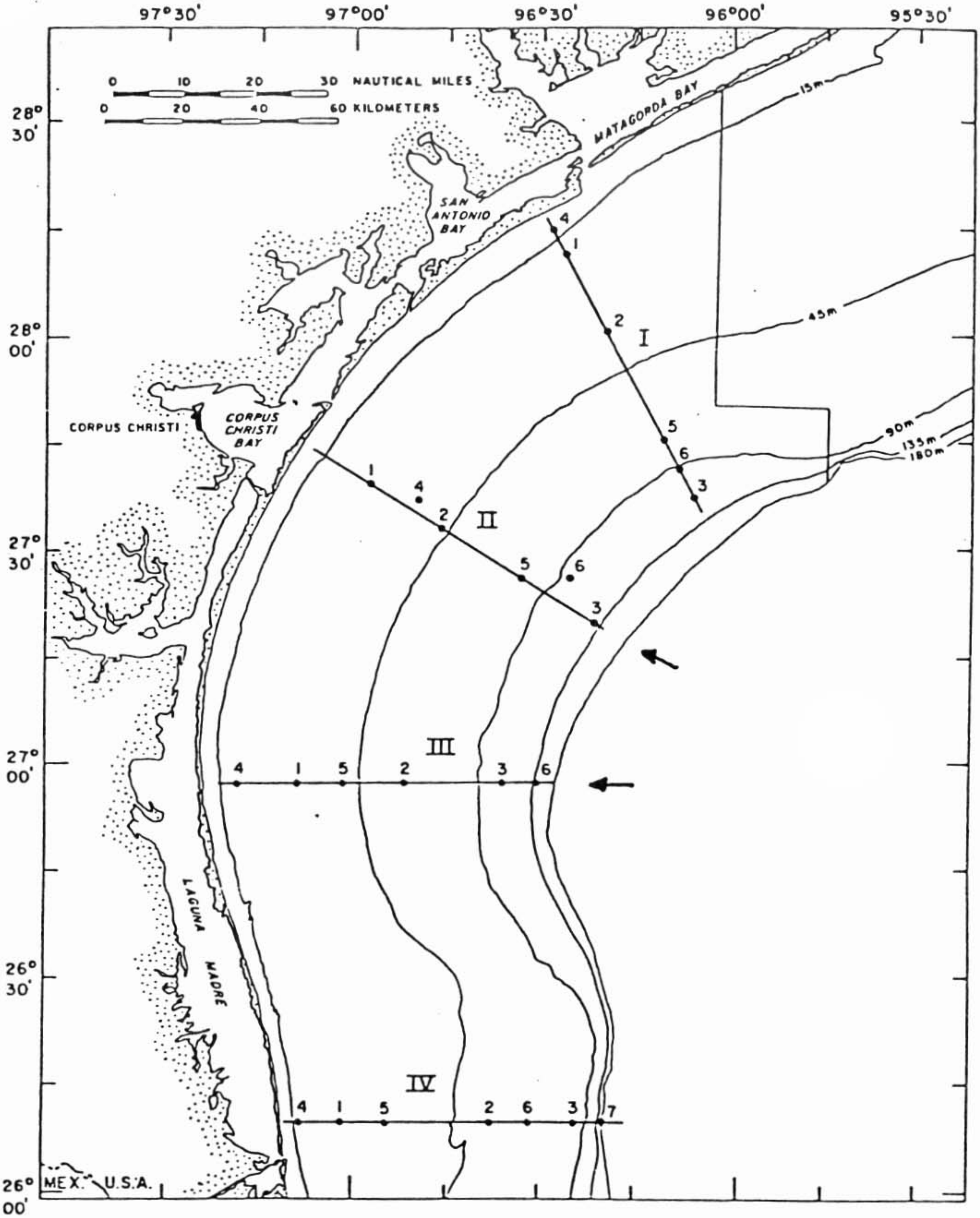

Figure 123a. Biologic infaunal stations from which subsamples were taken for trace metal analyses.

APPENDIX E

AUTHORITY OF TEXAS STATE AGENCIES
FOR OIL SPILL PREVENTION AND RESPONSE

State Agency / Operation	GLO	TDWR	TDH/DPS	Navigation Districts Cities/Ports	RRC	P&W
Leasing submerged tracts	TNRC 52.032 TNRC 52.085 TNRC 52.011 135.16.01.001-.002			TWC 60.034-.037		TWC 26.129 127.20.01.003-.004
Exploration (drilling)	TNRC 52.032 TNRC 34.005 TWC 51.117(d) 126.16.01.007 135.16.03.001-.008			TWC 61.117(d)	.051.02.02.007-.008 .051.02.02.011, .013,.017-.022 TNRC 91.101 TWC 26.131 P&WC 23.013	
Production facilities	TNRC 52.132 135.16.03.001-.008	Contingency Plan .007(c) Contingency plan appendix C2,6			TNRC 91.101 TWC 26.131 .051.02.02.024,.026 .051.02.02.008	
Storage & containment areas				TWC 60.101 TWC 61.151 TWC 63.153		
Barge traffic					.051.02.02.008(d)(2)(C)	
Waste Discharge	135.16.03.006-.007	TWC 26.039 TWC 26.041 TWC 26.121 TWC 27.011 Water Quality Standards	TWC 26.130		TNRC 91.015 TWC 27.031-.034 TWC 27.051-.056 .051.02.02.008(d)(2)(C)	
Pipelines	135.16.03.009-.011 135.16.03.005 126.18.02.002(b)(1)	Contingency plan appendix C4,8		TWC 19.001 TWC 19.037	.051.02.02.070 .051.02.02.071(a)(19)	
Abandoment/ Curtailment	135.16.03.014				TNRC 89.001 TNRC 89.041 TNRC 91.101 .051.02.02.014-.015	
Transport/ Unloading		Contingency plan appendix C4		TWC 60.071-.073 TWC 61.151 TWC 19.001 TWC 19.037 TWC 19.101 VAC art. 8249 VAC art. 1183-1187-1		
Lightering				TWC 60.101 TWC 61.151 TWC 63.153		
Coordination		TWC 26.261 et seq TWC 26.127 TWC 26.039,.041 contingency plan .004,.006,.007	VAC art. 6889.7		.051.02.02.071(a)(19)	127.20.20.002
Cleanup		TWC 26.261 et seq Contingency plan .006(b)		TNRC 61.162 TNRC 61.077	.051.02.02.008(d)(2) (H-I)	
other major response	TNRC 52.085	TWC 26.268	P&WC 76.116 76.205-.206 301.74.02.002		.051.02.02.008(d)(3) .051.02.02.011(d)(2) (A)(i)	P&WC 76.116 P&WC 76.205,.212 P&WC 77.004 127.20.20.004

APPENDIX F

TEXAS SYSTEM OF NATURAL LABORATORIES INC.

A RESOURCE FOR TEXAS AND THE NATION

CREDENTIALS

The Texas System of Natural Laboratories, Inc., (TSNL) is a Texas non-profit private corporation, with a 501(c)3 IRS determination, and has a current HEW Predetermined Indirect Costs Rate of 22% of Direct Costs for contracting purposes for federal funds.

TSNL was chartered in 1967 by Abner V. McCall, John C. Calhoun, and W. Frank Blair, acting as private citizens for the benefit of all public and private colleges and universities in Texas. Today these 144 academic institutions are the TSNL member institutions. Representatives from 61 schools operate TSNL in service for all. Abner V. McCall, J.D., President of Baylor University, today is Chairman of the Board for the thirteenth successive year.

Documentation of capability is available from TSNL Secretary-Treasurer Nevenna Tsanoff Travis at the TSNL central offices in Austin, Texas.

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TELS (512) 477-4925, 477-4934, 444-4479

TEXAS SYSTEM OF NATURAL LABORATORIES INC.

A RESOURCE FOR TEXAS AND THE NATION

PROGRESS REPORT: Texas System of Natural Laboratories, Inc., Land and Life Systems Encyclopedia for Texas

BY: Nevenna Tsanoff Travis, Secretary-Treasurer and System Coordinator, Laboratory Index Series, Project Director

DATE: March 26, 1979

Texas System of Natural Laboratories, Incorporated (TSNL) is a consortium of 61 Texas universities and colleges. These institutions operate TSNL as a private non-profit Texas corporation, of federal status 501(c)3, which, through its operation as a clearing house, serves all Texas general academic institutions (144 universities, colleges, community colleges, and junior colleges). Seed money for the clearinghouse are appropriated state trusteed funds, Texas Coordinating Board contract.

TSNL's primary goal is to secure controlled use of lands for research and to put scientists and students on those lands for field work and ecological studies. Public lands are available for research, and many owners of private and industrial lands in Texas are generously cooperating with TSNL. The lands are being inventoried in a laboratory index series of publications. This encyclopedic inventory of accessible research lands is building interest statewide in field work among all Texas general academic institutions, facilitating their search for teaching and research plots.

Schools everywhere seek comprehensive environmental base line information to be used in various disciplines including the natural and social sciences, business, engineering, architecture, and planning. Experience is now showing that the availability of such comprehensive base line data is equally important to industry and government. Copies of TSNL publications are being placed in academic libraries, state depository libraries where possible and appropriate, and in secondary school libraries as requested. Copies are given to individual permit holders, faculty, and others as needed. Publications to date include:

1. Laboratory Index 1-74, Edwards Plateau/Balcones Escarpment-Blackland Natural Laboratory, Bell, Williamson Counties, 1974, 18 pages
2. Laboratory Index 2-74, Lampasas Cut Plain Natural Laboratory, Bell County, 1974, 18 pages
3. Laboratory Index 3-74, Gulf Coast Prairie Natural Laboratory, Galveston County, 1974, 18 pages
4. TSNL Bulletin: Volume 1, No. 1, 1975
5. TSNL Bulletin: Volume 1, No. 2, 1975
6. TSNL Review, Volume 1, No. 1, 1975
7. TSNL Laboratory Index Series 4-76, Hueco Tanks State Historical Park, El Paso County, 1976, 50 pages
8. TSNL Laboratory Index Series 5-76, Southern Hueco Mountains, El Paso County, 1976, 51 pages
9. TSNL Laboratory Index Series LIS-R-1-76, Gulf Coast Region, 36 Counties, Texas, 1976, 416 pages (1000 charts) Draft I, Section 1
10. International Base Line Data Coding System for Relating Regional Fundamental Knowledge Inventory records, Draft for Review, 1977, 236 pages
11. TSNL Laboratory Index Series LIS-R-1-78, 1,930 charts, Texas Gulf Coast 36 Counties, Algae, Mollusks, Vascular Plants (Hydrocharitaceae, Lamiaceae, Najadales, Poaceae, Scrophulariaceae), Human Ecology (Archaeology, 13 counties; Socioeconomics, 36 counties)

Publications in preparation include:

1. TSNL Laboratory Index Series LIS-R-1-79, Texas Gulf Coast 36 Counties, Meteorology (revised LIS-R-1-76), Vascular Plants (Euphorbiaceae, Solanaceae), Texas Fish, Archaeology (23 counties), Demography (revised LIS-R-1-76), Socioeconomics (revised LIS-R-1-76)
2. Six unit indexes in manuscript, 50-100 pages each, projected publication in 1979 as funding allows
3. Species profiles in manuscript and in drafting: wetland plants (93), other plants (52), crustacea (oysters, shrimp, 12), fish (600), birds (109), mammals (22)

Unit inventories, indexing a single research plot, are expensive to prepare and production lags behind the existing need. Therefore the TSNL emphasis has shifted toward regional indexing. The regional index provides a county-wide overview with footnotes, bibliography, an inventory of other research resources, and potential research topics. Ultimately, seven such regional inventory volumes, stored in the computers by county, species, and latitude/longitude, will become the published land and life systems encyclopedia for the whole state of Texas. Provision is being made to up-date and revise on an ongoing basis. Footnotes, bibliographies, and data systems references in these volumes will enable the students doing research at even the smallest community college to share the information resources of the great government and university research databanks, collections, and libraries through interlibrary loan.

TSNL's first regional index concerns 36 counties of the Gulf Coast. Draft I is the work of graduate student compilers. This work of the students is constantly being reviewed, revised, and added to by senior faculty. A partial draft was photocopied in February 1977 and given out to faculty and others for revision and review (LIS-R-1-76). In fiscal year 1978 under matching HUD-701 funds from the Governor's Office of Budget and Planning, and a Grant from the Caesar Kleberg Foundation for Wildlife Conservation, 1930 charts were developed (LIS-R-1-78). Charting was continued in 1978 with Kleberg Foundation moneys, and now in 1979 with a Grant from the Texas Coastal and Marine Council.

All the data compilations in the regional indexes are being designed for automation. Care has been taken to draft a master outline which is international in scope and compatible with the needs of planning, modeling, management, and fundamental research. It is intended to be used also as a communications medium between data systems of researchers worldwide. The final version of the master outline will have been the work of faculty and government experts, many of them recognized world authorities in their field of study. A programming design for reference by county, by latitude/longitude, and by species allowing maximum flexibility for interrelating categories is being developed at this time as a pilot project in cooperation with the Texas Natural Resources Information System, Systems General.

Usual activities in support of research needs of students and faculty are ongoing. TSNL was invited to give a poster session at the January 2 to 4, 1979, meeting of the American Society of Limnology and Oceanography in Corpus Christi. The regional Gulf coast atlases, and Laboratory Index Series pilot project computer maps attracted widespread favorable attention. For information concerning available natural laboratories write to Texas System of Natural Laboratories, Inc.

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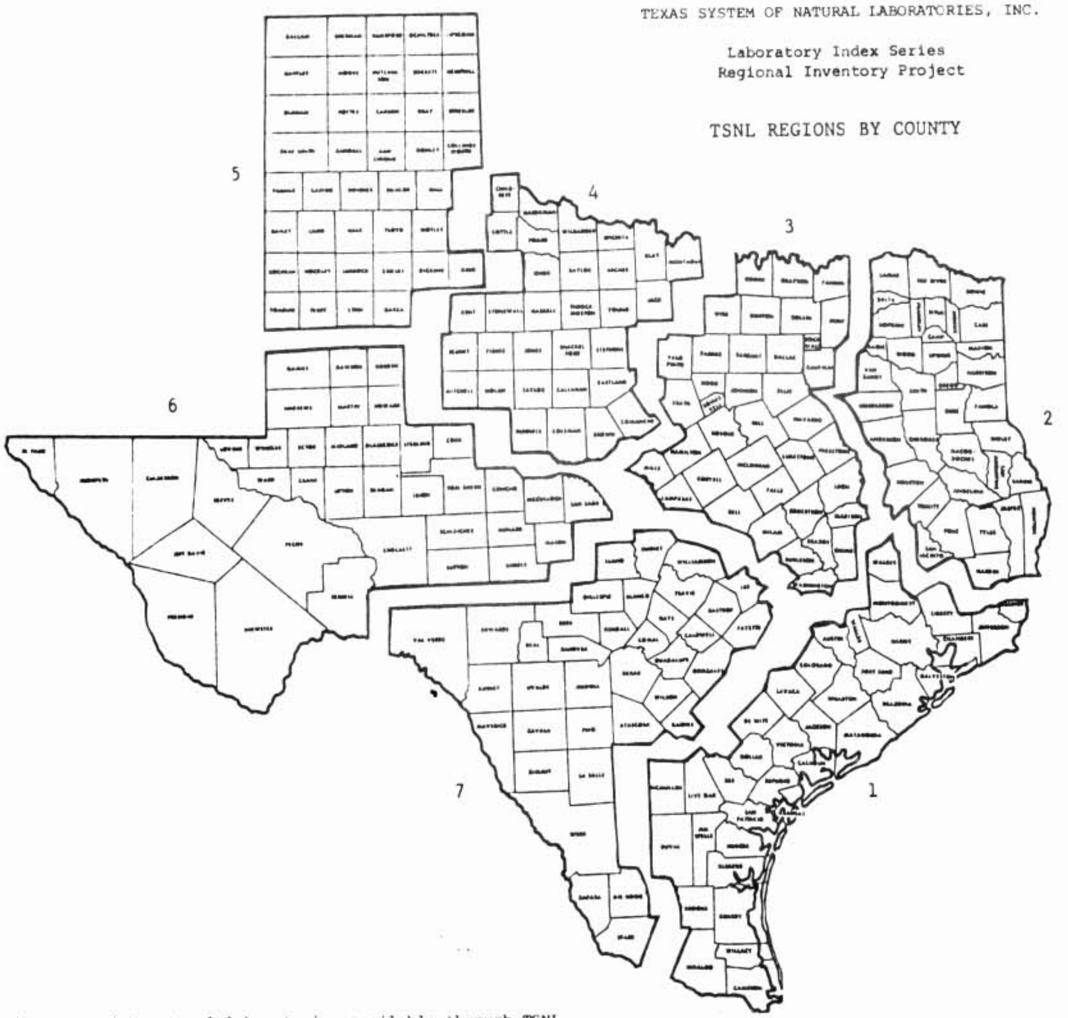
TEXAS SYSTEM OF NATURAL LABORATORIES, INC.

Laboratory Index Series
Regional Inventory Project

TSNL REGIONS BY COUNTY



1. GULF COAST

*Aransas (004)
Austin (008)
*Bee (013)
*Brazoria (020)
Brooks (024)
*Calhoun (029)
*Cameron (031)
*Chambers (036)
*Colorado (045)
DeWitt (062)
*Duval (066)
*Fort Bend (079)
*Galveston (084)
*Goliad (088)
*Harris (101)
*Hidalgo (108)
*Jackson (120)
*Jefferson (123)
*Jim Wells (125)
*Kenedy (131)
*Kleberg (137)
Lavaca (143)
*Liberty (146)
*Live Oak (149)
*McMullen (156)
*Matagorda (161)
*Montgomery (170)
*Nueces (178)
*Orange (181)
*Refugio (196)
*San Patricio (205)
*Victoria (235)
*Walker (236)
Waller (237)
*Wharton (241)
*Willacy (245)

* County with natural laboratories available through TSNL

2. EAST

*Anderson (001)
*Angelina (003)
*Bowie (019)
Camp (032)
*Cass (034)
*Cherokee (037)
Delta (060)
*Franklin (080)
*Gregg (092)
*Hardin (100)
*Harrison (102)
*Henderson (107)
Hopkins (112)
*Houston (113)
*Jasper (121)
Lamar (139)
*Marion (158)
*Morris (172)
*Nacogdoches (174)
*Newton (176)
*Panola (183)
*Polk (187)
*Rains (190)
*Red River (194)
*Rusk (201)
*Sabine (202)
*San Augustine (203)
*San Jacinto (204)
*Shelby (210)
Smith (212)
Titus (225)
*Trinity (228)
*Tyler (229)
*Upshur (230)
*Van Zandt (234)
*Wood (250)

3. NORTH CENTRAL

*Bell (014)
*Bosque (018)
Brazos (021)
*Burleson (026)
*Collin (043)
*Cooke (049)
*Coryell (050)
Dallas (057)
Denton (061)
Ellis (070)
*Erath (072)
Falls (073)
*Fannin (074)
*Freestone (081)
*Grayson (091)
*Grimes (093)
*Hamilton (097)
*Hill (109)
*Hood (111)
Hunt (116)
Johnson (126)
*Kaufman (129)
*Lampasas (141)
*Leon (145)
*Limestone (147)
McLennan (155)
*Madison (157)
*Milam (166)
*Mills (167)
Navarro (175)
*Palo Pinto (182)
*Parker (184)
*Robertson (198)
*Rockwall (199)
*Somervell (213)
Tarrant (220)
Washington (239)
*Wise (249)

4. WEST CENTRAL

*Archer (005)
*Baylor (012)
*Brown (025)
*Callahan (030)
*Childress (038)
*Clay (039)
*Coleman (042)
*Comanche (047)
*Cottle (051)
*Eastland (067)
*Fisher (076)
*Foard (078)
*Hardeman (099)
*Haskell (104)
*Jack (119)
*Jones (127)
*Kent (132)
*Knox (138)
*Mitchell (168)
*Montague (169)
Nolan (177)
*Runnels (200)
*Scurry (208)
*Shackleford (209)
*Stephens (215)
*Stonewall (217)
*Taylor (221)
*Throckmorton (224)
*Wichita (243)
*Wilbarger (244)
*Young (252)

5. PANHANDLE

*Armstrong (006)
*Bailey (009)
*Briscoe (023)
*Carson (033)
*Castro (035)
*Cochran (040)
*Collingsworth (044)
Crosby (054)
*Dallam (056)
*Deaf Smith (059)
*Dickens (063)
*Donley (065)
Floyd (077)
Garza (085)
*Gray (090)
*Hale (095)
*Hall (096)
*Hansford (098)
Hartley (103)
*Hemphill (106)
*Hockley (110)
*Hutchinson (117)
King (135)
*Lamb (140)
*Lipscomb (148)
Lubbock (152)
*Lynn (153)
*Moore (171)
*Motley (173)
Ochiltree (179)
*Oldham (180)
*Parmer (185)
*Potter (188)
*Randall (191)
*Roberts (197)
Sherman (211)
*Swisher (219)
*Terry (223)
*Wheeler (242)
*Yoakum (251)

6. WEST

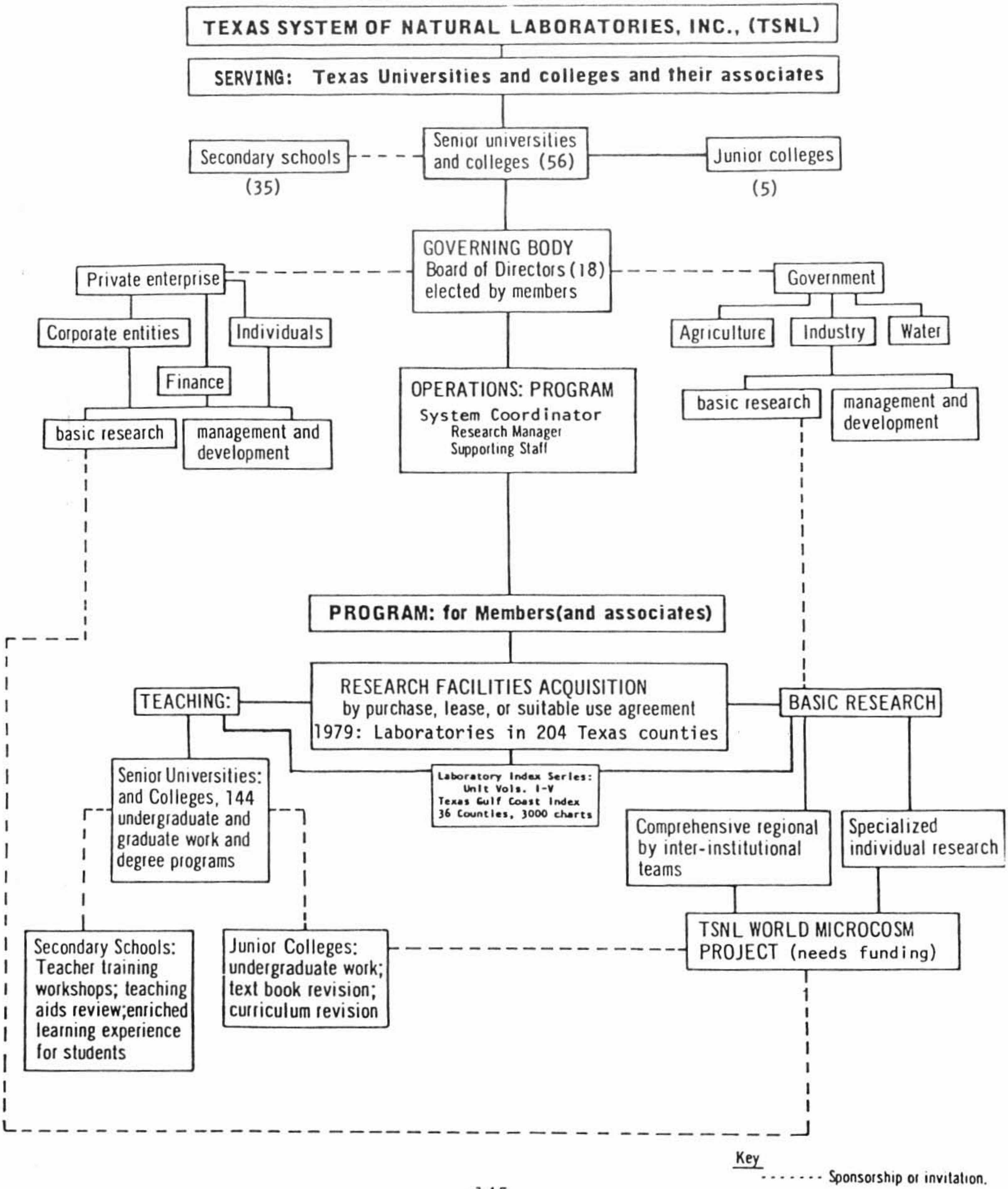
*Andrews (002)
*Borden (017)
*Brewster (022)
*Coke (041)
Concho (048)
*Crane (052)
*Crockett (053)
*Culberson (055)
*Dawson (058)
Ector (068)
*El Paso (071)
*Gaines (083)
Glasscock (087)
*Howard (114)
*Hudspeth (115)
*Irion (118)
*Jeff Davis (122)
*Kimble (134)
*Loving (151)
McCulloch (154)
*Martin (159)
Mason (160)
Menard (164)
*Midland (165)
*Pecos (186)
*Presidio (189)
*Reagan (192)
*Reeves (195)
San Saba (206)
Schleicher (207)
*Sterling (216)
Sutton (218)
*Terrell (222)
*Tom Green (226)
*Upton (231)
*Ward (238)
*Winkler (248)

7. SOUTH CENTRAL

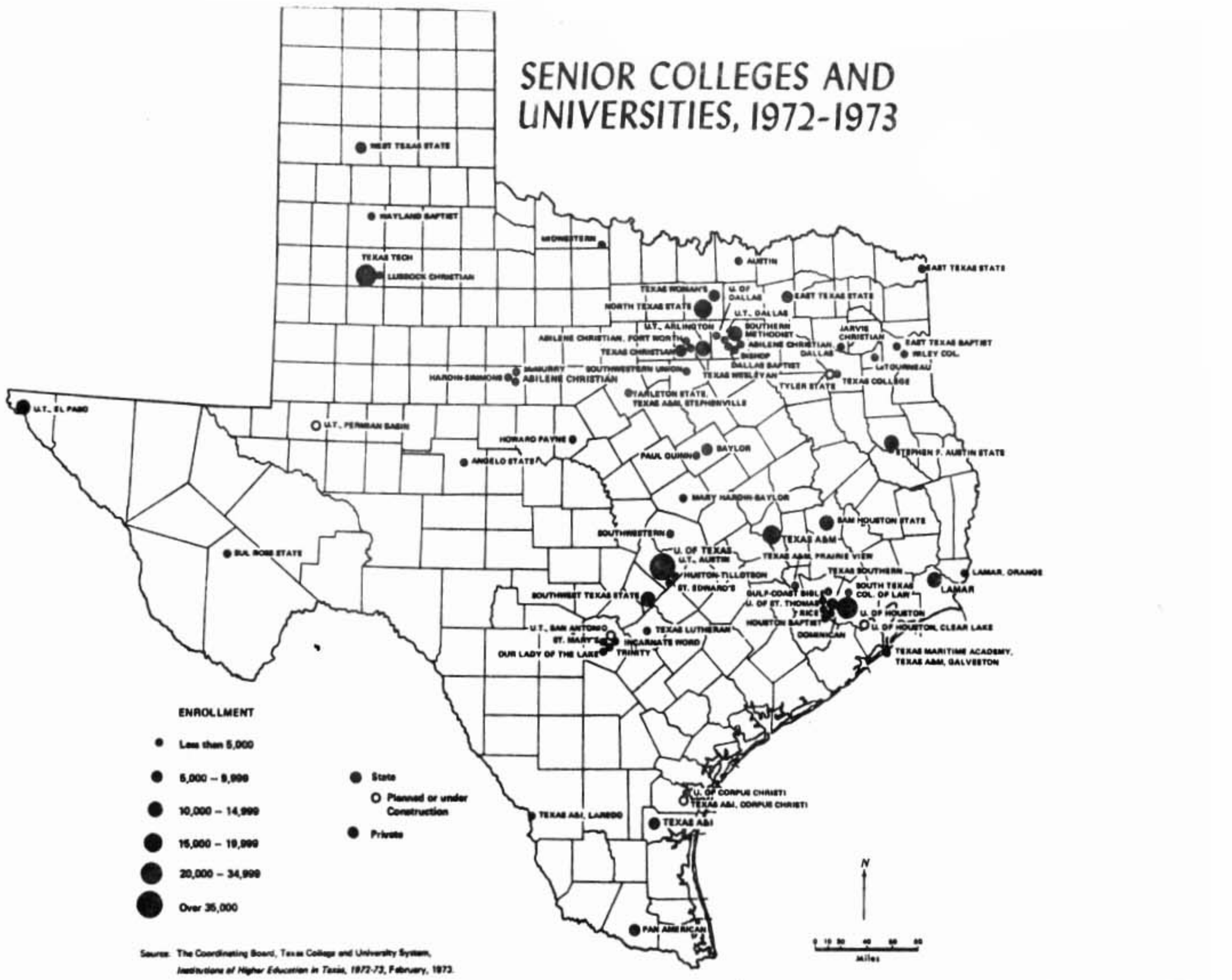
*Atascosa (007)
*Bandera (010)
*Bastrop (011)
*Bexar (015)
*Blanco (016)
*Burnet (027)
Caldwell (028)
Comal (046)
*Dimmit (064)
*Edwards (069)
Fayette (075)
*Frio (082)
*Gillespie (086)
*Gonzales (089)
Guadalupe (094)
*Hays (105)
Jim Hogg (124)
Karnes (128)
Kendall (130)
*Kerr (133)
Kinney (136)
*La Salle (142)
*Lee (144)
Llano (150)
*Maverick (162)
*Medina (163)
Real (193)
*Starr (214)
*Travis (227)
*Uvalde (232)
*Val Verde (233)
*Webb (240)
*Williamson (246)
*Wilson (247)
*Zapata (253)
Zavala (254)

March 26, 1979

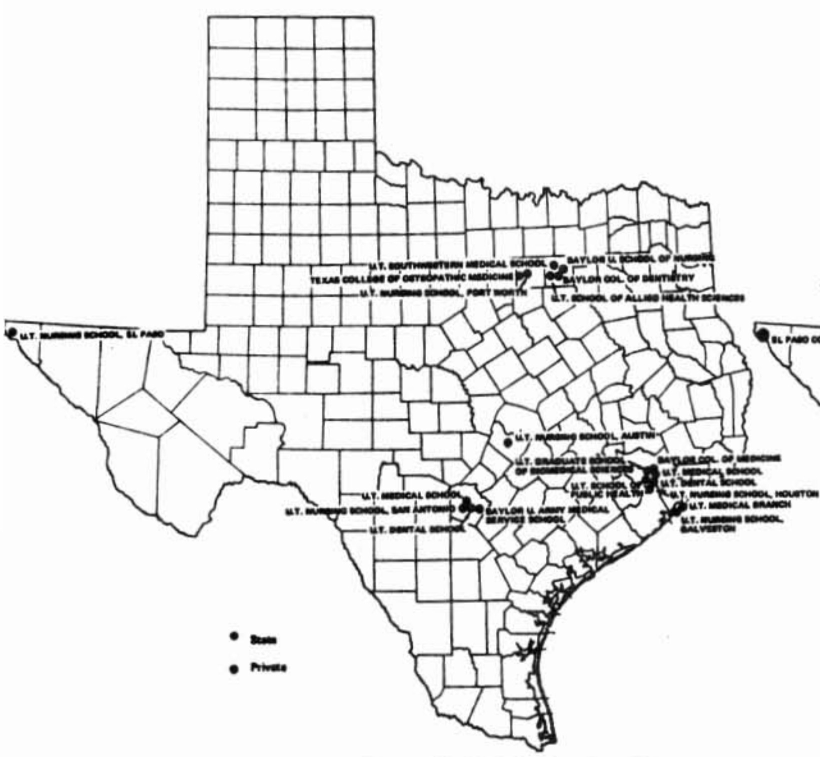
OPERATIONS CHART, 1978-1979



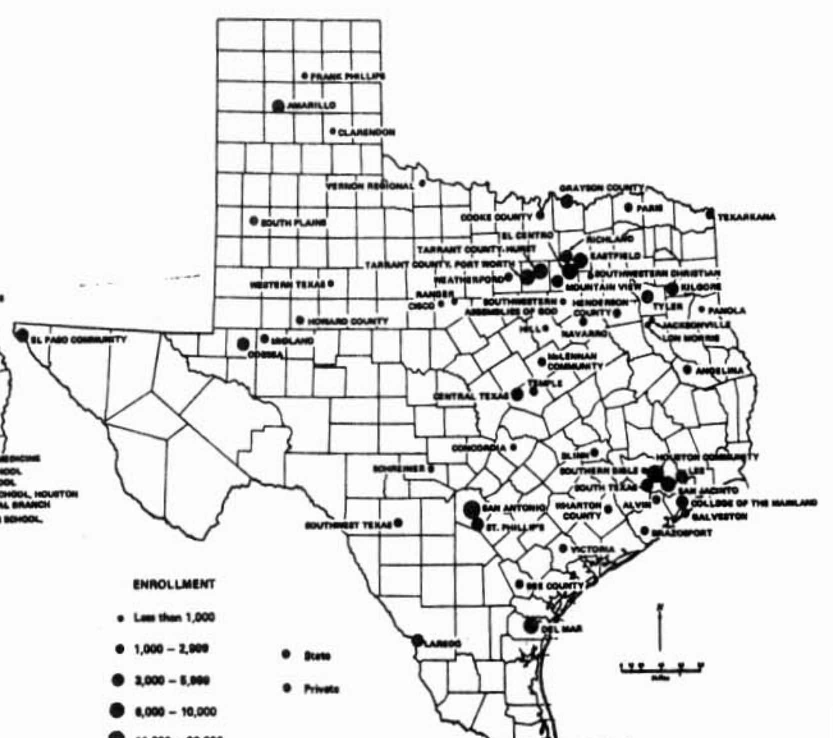
SENIOR COLLEGES AND UNIVERSITIES, 1972-1973



MEDICAL AND DENTAL SCHOOLS, 1972-1973



JUNIOR COLLEGES, 1972-1973



Arbingast, S. A.; L. G. Kennamer; R. H. Ryan; A. Lo; D. L. Karney; C. P. Zlatkovitch; M. E. Bonine; and R. G. Steele. 1973. *Atlas of Texas*. Austin: Bureau of Business Research, The University of Texas at Austin.